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JADS JT&E

End-to-End Test Interim Report Phase 4

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Joint Advanced Distributed Simulation
Joint Test Force
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EXECUTIVE SUMMARY

1.0 Introduction

This executive summary serves as a stand-alone document as well as part of this report. For that reason, the reader will find some duplication of verbiage and figures.

2.0 JADS Overview

The Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation was chartered by the Office of the Under Secretary of Defense (Acquisition and Technology) in October 1994 to investigate the utility of advanced distributed simulation (ADS) technologies for support of developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). The program is Air Force led with Army and Navy participation. The program is currently scheduled to end in March 2000.

The JADS Joint Test Force is directly investigating ADS applications in three slices of the test and evaluation (T&E) spectrum: the System Integration Test (SIT) explored ADS support of air-to-air missile testing; the End-to-End (ETE) Test investigated ADS support for command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) testing; and the Electronic Warfare (EW) Test explored ADS support for EW testing. Phase 4 of the ETE Test is the subject of this report.

3.0 ETE Test Overview

The ETE Test was designed to evaluate the utility of ADS to support testing of C4ISR systems. The test focused on the Joint Surveillance Target Attack Radar System (Joint STARS) as one component of a representative C4ISR system. The ETE Test also evaluated the capability of the JADS Test Control and Analysis Center (TCAC) to control a distributed test of this type and remotely monitor and analyze test results.

The ETE Test consisted of four phases. Phase 1 developed or modified the components needed to develop the ADS test environment. Phase 2 used the ADS test environment to evaluate the utility of ADS to support DT&E and early OT&E of a C4ISR system in a laboratory environment. Phase 3 transitioned portions of the architecture to the E-8C aircraft, ensured that the components functioned properly, and checked that the synthetic environment interacted properly with the aircraft and actual light ground station module (LGSM). Phase 4 evaluated the ability to perform testing and evaluation in a ADS-enhanced live test environment.

4.0 Overview of ETE Test Phase 4

4.1 Purpose

Phase 4 determined the utility of ADS in performing test and evaluation in an ADS-enhanced live test environment. The test objectives were

JADS Issue 1. What is the present utility of ADS, including distributed interactive simulation (DIS), for T&E?

JADS Objective 1-1. Assess the validity of data from tests utilizing ADS, including DIS, during test execution.

JADS Objective 1-2. Assess the benefits of using ADS, including DIS, in T&E.

JADS Issue 2. What are the critical constraints, concerns, and methodologies when using ADS for T&E?

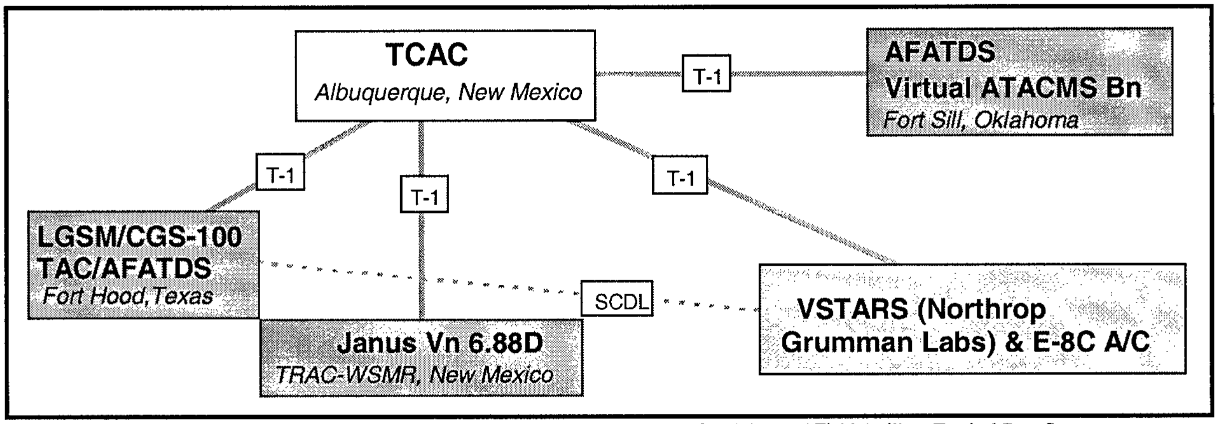
JADS Objective 2-1. Assess the critical constraints and concerns in ADS performance for T&E.

JADS Objective 2-2. Assess the critical constraints and concerns in ADS support systems for T&E.

JADS Objective 2-3. Develop and assess methodologies associated with ADS for T&E.

4.2 Approach

Figure ES-1 provides an overview of the Phase 4 ETE Test synthetic environment.



A/C = aircraft
AFATDS = Advanced Field Artillery Tactical Data System
ATACMS = Army Tactical Missile System
Bn = battalion
Janus = interactive, computer-based simulation of combat operations
SCDL = surveillance control data link
T-1 = digital carrier used to transmit a formatted digital signal at 1.544 megabits per second
TAC = target analysis cell
TRAC - U.S. Army Training and Doctrine Command Analysis Center
VSTARS = Virtual Surveillance Target Attack Radar System
WSMR = White Sands Missile Range, New Mexico

Figure ES-1. ETE Test Phase 4 Synthetic Environment

The ETE Test used the Janus 6.88D simulation to generate the entities representing the elements in the rear of a threat force. The U.S. Army Training and Doctrine Command Analysis Center (TRAC) at White Sands Missile Range (WSMR), New Mexico, provided the Janus scenario feed.

The Test Control and Analysis Center in Albuquerque, New Mexico, provided test control.

The Joint STARS E-8C simulation, called the Virtual Surveillance Target Attack Radar System (VSTARS), represented the radar subsystem of the Joint STARS E-8C when the test was operating in a laboratory environment. It consisted of a distributed interactive simulation network interface unit, a radar processor simulator and integrator (RPSI) that contained the two real-time radar simulations with necessary databases, and various simulations of E-8C processes. VSTARS was operated at the Northrop Grumman Surveillance and Battle Management Systems facility in Melbourne, Florida.

When the test was conducted in a live mode, an ADS-enhanced E-8C provided live, virtual, and mixed radar reports. The ADS-enhanced E-8C consisted of the T3 aircraft with the RPSI and the air network interface unit added as described in the Phase 3 report.

The LGSM and target analysis cell (TAC) were represented by Bravo Company, 303d Military Intelligence Battalion. Fire support, in the form of the Advanced Field Artillery Tactical Data System (AFATDS), was represented by soldiers from the 4th Infantry Division (Mechanized). Communications among these command, control, communications, computers and intelligence (C4I) systems employed doctrinally correct means.

The Tactical Army Fire Support Model (TAFSM) simulation modeled the Army Tactical Missile System (ATACMS) battalion and sent the fire and detonate protocol data units (PDUs) to the Janus 6.88D simulation. Janus then modeled the engagement results and reflected them in the synthetic environment.

5.0 ETE Test Phase 4 Results

5.1 Fulfillment of Test Objectives

All ETE Test Phase 4 objectives were met. The ETE Test team determined that the use of an ADS-enhanced live test environment strengthened the operational testing of C4ISR systems of systems and resulted in the collection of valid data.

During Phase 4, the critical constraints, concerns, and methodologies associated with using an ADS-enhanced test environment for test and evaluation were also evaluated.

The ETE Test team also investigated, for the first time, the use of satellite communications to transmit simulation data to an aircraft in flight, thereby extending ADS-enhanced testing into a new dimension.

Finally, the ETE Test team developed and assessed test control and data collection methodologies useful for ADS testing.

6.0 Lessons Learned

6.1 Technical

Testers should carefully plan the development of the simulations and links comprising their ADS environment. During test execution, they must ensure that the time sources are synchronized and continuously monitor PDU traffic. The distributed nature of ADS testing necessitates special equipment for network check-out and verification and requires strict configuration control of analysis tools and collected data.

6.2 Infrastructure and Process

ADS test planning should be detailed enough to encompass key requirements at the earliest possible stages, yet flexible enough to accommodate unexpected situations during test execution. A conservative development approach is recommended -- accomplish risk reduction activities before each ADS test and let each ADS test build on the success of earlier experiments. Successful test execution requires effective internode communication, test and resource control, and data management procedures.

7.0 Conclusions

7.1 Utility

An ADS-enhanced live environment can strengthen OT&E of C4ISR systems. In comparison with conventional tests, an ADS-enhanced test allows the examination of C4ISR systems under realistic conditions for longer periods of time, over far larger battlespaces, and at a much lower cost. This versatile technology can provide test environments that include large numbers of entities, entities operating under realistic but unsafe conditions and joint and combined operations. ADS provides C4ISR system testers with greater flexibility in designing, executing, and analyzing their tests.

7.2 Technical

Phase 4 used both a conventional wide area network (WAN) and satellite communications to distribute data. The WAN exhibited low bandwidth usage and a low latency during the test. The satellite communications used all the available bandwidth and required buffering to handle periods of heavy scenario activity. The combination of buffering and transmission times produced relatively high latencies. The satellite communications also had a higher rate of data dropout than the WAN. All these effects had minimal impact on the test but should be considered when testing other C4ISR systems using satellite communications.

7.3 Infrastructure

Compared to conventional testing, ADS testing reduces the need for large numbers of fielded personnel and vehicles. The ability to automatically collect and analyze test data also reduces the number of people required for setup, execution, and analysis. ADS test success relies on well-organized test control and data management procedures. Distributed testing requires sophisticated instrumentation, trained personnel to operate and maintain that equipment, and funds to support personnel and equipment at distant test nodes.

1.0 Introduction

1.1 Joint Advanced Distributed Simulation Overview

The Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E) was chartered by the Deputy Director, Test, Systems Engineering and Evaluation (Test and Evaluation)[1], Office of the Under Secretary of Defense (OSD) (Acquisition and Technology) in October 1994 to investigate the utility of advanced distributed simulation (ADS) technologies for support of developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). The program is Air Force led with Army and Navy participation. Science Applications International Corporation (SAIC) and the Georgia Tech Research Institute provide contracted technical support. The program is currently scheduled to end in March 2000.

The JADS JT&E charter focuses on three issues: what is the present utility of ADS, including distributed interactive simulation (DIS), for test and evaluation (T&E); what are the critical constraints, concerns, and methodologies when using ADS for T&E; and what are the requirements that must be introduced into ADS systems if they are to support a more complete T&E capability in the future. From these issues, objectives and measures have been developed to guide the evaluation.

The JADS Joint Test Force (JTF) is directly investigating ADS applications in three slices of the T&E spectrum: the System Integration Test (SIT) explored ADS support of air-to-air missile testing; the End-to-End (ETE) Test investigated ADS support for command, control, communications, computers, and intelligence, surveillance and reconnaissance (C4ISR) testing; and the Electronic Warfare (EW) Test explored ADS support for EW testing. Each test applied the JADS objectives and measures as appropriate to conduct its evaluation. The JTF was also chartered to observe or participate at a modest level in ADS activities sponsored and conducted by other agencies in an effort to broaden conclusions developed in the three dedicated test areas.

Phase 4 of the JADS ETE Test is the subject of this report and is described in the next section; the following is a brief synopsis of the SIT and the EW Test.

The SIT evaluated the utility of using ADS to support cost-effective testing of an integrated missile weapon/launch aircraft system in an operationally realistic scenario. The SIT also evaluated the capability of the JADS Test Control and Analysis Center (TCAC) to control a distributed test of this type and to remotely monitor and analyze test results.

More detailed information on the SIT can be found in the test reports available at http://www.jads.abq.com. (After 1 March 2000 refer requests to Headquarters Air Force Operational Test and Evaluation Center (HQ AFOTEC)/History Office (HO), 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 or SAIC Technical Library, 2001 North Beauregard St. Suite 80, Alexandria, Virginia 22311.)

[1] This office is now the Deputy Director, Developmental Test and Evaluation (DD, DT&E).

The EW Test evaluated the utility of ADS in a distributed EW environment. The first phase was open air testing to develop a performance baseline for two subsequent test phases. The first distributed test phase employed a linked architecture using Department of Defense's (DoD) high level architecture (HLA), which included a digital simulation model of the ALQ-131 self-protection jammer, threat simulation facilities, and constructive models that support replication of the open air environment. In the second distributed phase, a live aircraft and jammer in an installed systems test facility was substituted for the digital model. In both distributed test architectures, system performance data were compared with live fly data for verification and validation (V&V).

More detailed information on the EW Test can be found in the test reports available at http://www.jads.abq.com. (After 1 March 2000 refer requests to HQ AFOTEC/HO, 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 or SAIC Technical Library, 2001 North Beauregard St. Suite 80, Alexandria, Virginia 22311.)

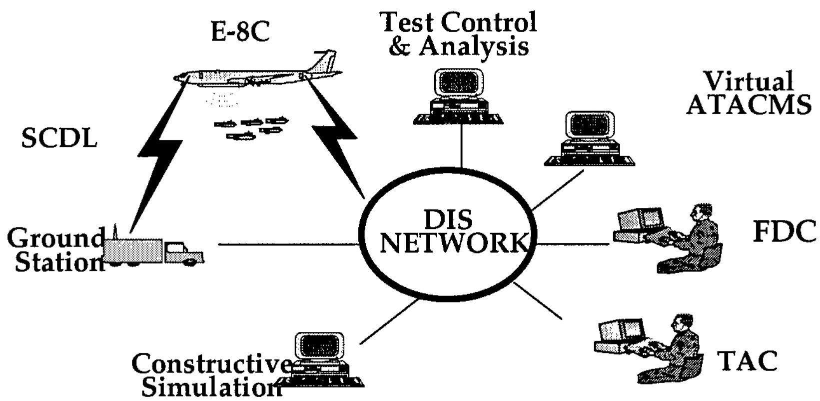
1.2 Test Overview

The ETE Test was designed to evaluate the utility of ADS to support testing of C4ISR systems. The test focused on the Joint Surveillance Target Attack Radar System (Joint STARS) as one component of a representative C4ISR system. The ETE Test also evaluated the capability of the JADS TCAC to control a distributed test of this type and to remotely monitor and analyze test results.

The ETE Test used ADS to assemble an enhanced environment for testing C4ISR systems. The intent was to provide a complete, robust set of interfaces from sensor to weapon system, including the additional intermediate nodes that would be found in a tactical engagement. The test traced a thread of the complete battlefield process from target detection to target assignment and engagement at corps level using ADS. It allowed the tester to evaluate the thread as a whole or the contribution of any parts individually and to evaluate what effects an operationally realistic environment had on the system under test (SUT).

The primary method used by the ETE Test to create an ADS-enhanced test environment was to seamlessly add additional entities to the battlefield seen by Joint STARS. In addition, some of the complementary suite of other command, control, communications, computers and intelligence (C4I) and weapon systems, with which Joint STARS would interact, were incorporated into the environment to create the target detection to target engagement loop. The additional entities and battlefield elements enabled the test team to evaluate the utility of an ADS-enhanced test environment.

The test concept (Figure 1) was to use the additional entities to supplement the operational environment experienced by the E-8C and light ground station module (LGSM) operators. By mixing available live targets with targets generated by a constructive model, a battle array approximating the major systems present in a notional corps area of interest was presented. Construction of a network with nodes representing appropriate C4I and weapon systems presented a more robust cross section of players for interaction with the E-8C and LGSM operators.



ATACMS = Army Tactical Missile System FDC = fire direction center SCDL = surveillance control data link
TAC = target analysis cell

Figure 1. ETE Test Conceptual Model

Several components were required to create the ADS-enhanced operational environment used in the ETE Test. In addition to Joint STARS, the ETE Test required a validated simulation capable of generating entities representing the rear elements of a threat force. The ETE Test team modified an Army verified and validated simulation, Janus, to meet this requirement. Also, a simulation of the Joint STARS radar was needed to insert the simulated entities into the radar stream on board the E-8C while it was flying a live mission. Other capabilities used to support the test included simulations or components of the Army's artillery command and control process and a simulation of the Army Tactical Missile System (ATACMS). Communications among these simulations were accomplished using such doctrinally correct means as the CGS-100, a subsystem of the Compartmented All Source Analysis System (ASAS) Message Processing System (CAMPS), remote ASAS workstations (RWSs), and the Advanced Field Artillery Tactical Data System (AFATDS).

The ETE Test consisted of four phases. Phase 1 developed or modified the components that allowed the mix of live and simulated targets at an E-8C operator's console and LGSM operator's console. Phase 2 verified and validated the simulations used in the ADS-enhanced environment and evaluated the utility of ADS to support DT&E and early OT&E of a C4ISR system in a laboratory environment. Phase 3 transitioned portions of the architecture to the E-8C aircraft, ensured that the components functioned properly, checked that the synthetic environment properly interacted with the aircraft and the actual LGSM, and repeated the V&V. Phase 4 evaluated the ability to conduct operational testing using an ADS-enhanced live test environment.

1.3 Phase 1 Overview

During Phase 1, software and hardware needed to establish the ETE Test ADS environment were developed, modified, and integrated. In addition, Phases 2 through 4 were planned.

The ETE Test ADS environment components developed or modified during Phase 1 included modification of a constructive simulation (Janus) to provide virtual targets, an E-8C radar simulation called the Virtual Surveillance Target Attack Radar System (VSTARS), an interface to allow surveillance control data link (SCDL) traffic from VSTARS to be displayed in the LGSM, and an initial ADS network suitable for integration and testing.

More detailed information on Phase 1 can be found in the *End-to-End Interim Report, Phase 1,* August 1998, available at http://www.jads.abq.com. (After 1 March 2000 refer requests to HQ AFOTEC/HO, 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 or SAIC Technical Library, 2001 North Beauregard St. Suite 80, Alexandria, Virginia 22311.)

1.3.1 Phase 1 Results

Phase 1 identified constraints associated with ADS testing. One key constraint was the ability of the DoD modeling and simulation infrastructure to support ADS-enhanced test and evaluation. A measure of this constraint is found in the amount of effort required to develop the simulations used in the ADS-enhanced test environment. Phase 1 illustrated the level of effort and associated costs involved in developing the supporting infrastructure for a test of this type.

Phase 1 demonstrated the value of applying a systems engineering methodology to identify the requirements for ADS components, evaluate the availability of ADS components, and modify or develop the components to meet the requirements.

Phase 1 established that suitable wide area networks (WAN) could be established and used for ADS-enhanced testing. Extensive testing established that available hardware and protocols were able to handle the expected load and that network latency did not appear to be a problem. After a through investigation of existing logging software, none of which proved suitable, it was decided to develop a JADS logger and player. This software would be used to collect test data and to provide post-test playback of data for analysis, troubleshooting and training.

Data analysis tools were also developed to aid in the analysis of test data. These tools were incorporated into a single tool called the JADS Analysis Toolbox. Some of the features include protocol data unit (PDU) analysis in near real time, predefined analyses and outputs, conversion of binary log file data to text data, PDU replay, and conversion utilities.

1.4 Phase 2 Overview

Phase 2 of the ETE Test determined the utility of ADS to support DT&E and early OT&E of a C4ISR system in a laboratory environment.

In Phase 2, the E-8C aircraft was represented by a laboratory-based simulation, VSTARS, that emulated the E-8C aircraft and provided the radar reports needed to drive the radar displays on the Advanced Technology Work Station (ATWS) and the LGSM. The Janus model simulated the threat battlefield entities. The radar reports from VSTARS were provided to an actual target analysis cell (TAC) for analysis and target assignment. Fire support missions were tasked using AFATDS messages sent to the Tactical Army Fire Support Model (TAFSM). TAFSM then simulated the launch, flyout, and detonation of an ATACMS missile. Janus calculated the results of the missile impact and reported them to VSTARS. In addition, the Janus operator could alter the scenario to reflect combat actions taken as a result of the missile strike. These data were also reported to VSTARS, and the resulting radar reports reflected the effects of the missile strike.

More detailed information on Phase 2 can be found in the *End-to-End Interim Report, Phase 2,* February 1999 available at http://www.jads.abq.com. (After 1 March 2000 refer requests to HQ AFOTEC/HO, 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 or SAIC Technical Library, 2001 North Beauregard St. Suite 80, Alexandria, Virginia 22311.)

1.4.1 Phase 2 Results

All ETE Test Phase 2 objectives were met. Phase 2 of the ETE Test illustrated the utility of ADS to support DT&E and early OT&E of a C4ISR system in a laboratory environment. Specific ETE Test Phase 2 results:

- An ADS environment can dramatically enhance C4ISR system DT&E and early OT&E.

- ADS testing provides the ability to test C4ISR systems of systems prior to the development of major systems that make up the systems of systems.

- The Phase 2 test required only a small part of the available WAN bandwidth and exhibited a low PDU latency rate comparable with earlier tests.

- The ETE Test WAN was highly reliable during Phase 2 testing, largely because of the ETE Test team's extensive pretest risk reduction efforts.

- The requirement to field large numbers of personnel and vehicles to test complex C4ISR systems is greatly reduced when ADS is used to augment the battlefield.

- An ADS laboratory environment can also be used for test planning, rehearsal, and execution.

- Valid test data can be collected using an ADS laboratory environment.

Phase 2, also identified critical constraints, concerns, and methodologies associated with using ADS for test and evaluation and developed and assessed test control and data collection methodologies useful for ADS testing.

1.5 Phase 3 Overview

The ETE Test Phase 3 provided an iterative step in determining the utility of ADS to the T&E of a C4ISR system. During this phase, portions of the architecture were transferred to the E-8C aircraft, the components were checked to make sure that they functioned properly, and the synthetic environment was checked to make sure that it interacted properly with the aircraft and actual ground station module (GSM).

Phase 3 focused on migrating certain software components of VSTARS, specifically the air network interface unit (ANIU) and the radar processor simulator and integrator (RPSI), from the laboratory Alpha workstations to the primary mission equipment on the T3 E-8C aircraft. In addition, the ground network interface unit (GNIU) software was separated from VSTARS and migrated to an Alpha workstation collocated with a satellite transceiver.

More detailed information on Phase 3 can be found in the *End-to-End Interim Report, Phase 3,* May 1999 available at http://www.jads.abq.com. (After 1 March 2000 refer requests to HQ AFOTEC/HO, 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 or SAIC Technical Library, 2001 North Beauregard St. Suite 80, Alexandria, Virginia 22311.)

1.5.1 Phase 3 Results

The ETE Test team successfully collected performance data on the network environment, while it operated during Phase 3. In addition, the ETE Test team developed and assessed test control and data collection methodologies useful for ADS testing.

A series of formal system integration tests (SIT) of the Joint STARS aircraft with the radar simulation operating was performed by the Joint STARS JTF.

The ETE Test team also conducted a formal V&V of the VSTARS software on board the aircraft.
The testing used recorded Janus vignettes played from equipment located in the Northrop Grumman laboratory, then broadcast via a satellite communications (SATCOM) link to the aircraft located on the tarmac. A GSM, located at the Joint STARS JTF facility, was used to verify SCDL linking functions with the aircraft. All the formal testing conducted by the Joint STARS JTF was completed successfully with only minor discrepancies noted. The V&V was conducted concurrently with the SIT.

2.0 Phase 4 Overview

2.1 Phase 4 Purpose

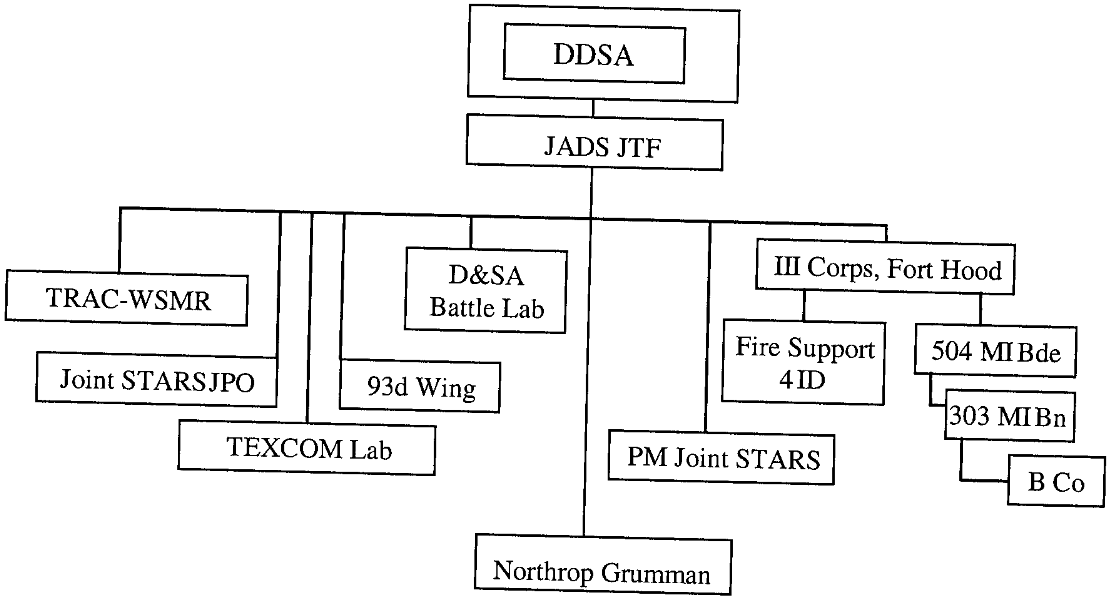
Phase 4 evaluated the ability to perform test and evaluation in a synthetically enhanced operational environment using typical operators.

2.2 Phase 4 Approach

All ETE Test Phase 4 objectives were met. The ETE Test team determined that the use of an ADS-enhanced live test environment strengthened the operational testing of C4ISR systems of systems and resulted in the collection of valid data.

Phase 4 determined the utility of ADS in augmenting a live, open air test mission of a C4ISR system. ADS was used, as in Phase 2, to present a synthetic environment that was more representative of an operational theater than would be found at a test range. The Phase 4 test was conducted over Fort Hood, Texas. A setup/rehearsal period was followed by the E-8C flying three test missions. The VSTARS in the Grumman laboratory, as discussed for Phase 2, was used for the remaining test missions. All SUT data collected from these live test missions were compared with previous test mission data collected during Phase 2 and the Phase 4 laboratory test. In addition, the synthetic environment was closely monitored to collect DIS component performance data, to assess the impact of DIS component performance on the SUT data, and to identify problems with DIS components and test methodologies that impact SUT data validity. These results were used, as appropriate, to help establish requirements for subsequent ADS technology growth.

Figure 2 shows the organizational structure for reporting and coordination during Phase 4 of the ETE Test.



Bde = brigade
D&SA = Depth and Simultaneous Attack
ID = infantry division
MI = Military Intelligence
TEXCOM = U.S. Army Test and Experimentation Command
WSMR = White Sands Missile Range
Bn = battalion
DDSA = deputy director, System Assessment
JPO = joint program office
PM = program manager
TRAC = U.S. Army Training and Doctrine Command Analysis Center
Co = company

Figure 2. ETE Test Organizational Structure

During Phase 4 testing, the roles and responsibilities of these organizations were as follows.

Deputy Director, System Assessment (DDSA)[2]

DDSA, Washington, District of Columbia:

- Oversaw the JADS Joint Test and Evaluation (JT&E)
- Approved JADS financial requirements
- Approved the program test plan (PTP)
- Oversaw the analysis and reporting of test results

JADS JTF

The JADS JTF, Albuquerque, New Mexico:

- Conducted overall planning, execution, analysis, and reporting of the test
- Managed funding to accomplish the test
- Developed and evaluated JADS issues, objectives, measures, and related data elements

[2] This office is now the Deputy Director, Developmental Test and Evaluation (DD, DT&E).

- Developed and integrated the components of the ETE Test ADS-enhanced live test environment
- Established necessary communication links with test participants
- Operated the Test Control and Analysis Center during testing
- Worked with other organizations in analyzing test data
- Reported interim and final results to OSD

U.S. Army Training and Doctrine Command Analysis Center (TRAC), White Sands Missile Range (WSMR)

TRAC-WSMR, New Mexico:

- Developed, tested, and documented Janus 6.88D (an expanded variant of Janus) for JADS
- Assisted in integrating Janus 6.88D into the ETE Test ADS-enhanced live test environment
- Assisted in database conversions
- Assisted in developing vignettes
- Assisted in verification, validation, and accreditation (VV&A) activities
- Assisted in ETE Test execution

U.S. Army Test and Experimentation Command (TEXCOM) Lab

The TEXCOM lab, Fort Hood, Texas:

- Assisted in scenario and vignette development
- Assisted in ETE Test execution

Depth and Simultaneous Attack (D&SA) Battle Lab

The D&SA Battle Lab, Fort Sill, Oklahoma:

- Provided and operated the TAFSM and AFATDS
- Assisted in the integration of the ETE Test ADS-enhanced live test environment
- Assisted in VV&A activities and ETE Test execution

U.S. Army III Corps

III Corps Headquarters, Fort Hood, Texas:

- B Company (Co), 303d Military Intelligence (MI) Battalion (Bn), 504 MI Brigade (Bde) supported the conduct of ETE Test Phase 2 and Phase 4 events with LGSM(s) and a target analysis cell (TAC) and assisted in the integration of the ETE Test ADS-enhanced live test environment
- 504 MI Bde provided a test environment for the ETE Test Phases 2 and 4
- Fire Support 4th Infantry Division (4 ID) provided an AFATDS and personnel to support the ETE Test Phase 4

Joint STARS Joint Program Office (JPO)

Joint STARS JPO, Hanscom Air Force Base (AFB), Massachusetts, provided access to the Joint STARS JTF and Northrop Grumman.

The Joint STARS JTF of the Joint STARS JPO in Melbourne, Florida:

- Supported conduct of testing in all phases
- Analyzed Joint STARS test results and provided evaluations according to JADS objectives
- Assisted in VV&A activities
- Provided operators during Phase 4 of the ETE Test

Northrop Grumman Aerospace Corporation

Northrop Grumman, Electronics and Systems Integration Division, Melbourne, Florida:

- Designed, developed and integrated the radar processor simulation and integrator
- Developed the Virtual Surveillance Target Attack Radar System
- Conducted and assisted in V&V activities
- Assisted in E-8C mission planning
- Operated VSTARS during ETE Test phases

Contracting with Northrop Grumman was conducted through Rome Laboratory in New York.

2.3 Test Objectives

Phase 4 determined the utility of ADS in performing test and evaluation in a synthetically enhanced live test environment.

The JADS issues, test objectives, and subobjectives for Phase 4 are described below. Each subobjective in turn encompassed one or more test measures. In Section 4 these issues, objectives, subobjectives, and test measures are discussed in terms of their intent, the associated data collection methodology, and operational test results.

JADS Issue 1. What is the present utility of ADS, including DIS, for T&E?

JADS Objective 1-1. Assess the validity of data from tests utilizing ADS, including DIS, during test execution.

JADS Objective 1-2. Assess the benefits of using ADS, including DIS, in T&E. This test objective was broken down into subobjectives.

JADS Subobjective 1-2-1. Assess ADS capability to support the early phases of the acquisition process.

JADS Subobjective 1-2-2. Assess ADS capability to support T&E planning and test rehearsal.

JADS Subobjective 1-2-3. Assess ADS capability to support T&E execution.

JADS Issue 2. What are the critical constraints, concerns, and methodologies when using ADS for T&E?

JADS Objective 2-1. Assess the critical constraints and concerns in ADS performance for T&E. This objective was broken down into subobjectives. (Subobjective 2-1-1 is not applicable to the ETE Test Phase 4.)

JADS Subobjective 2-1-2. Assess network and communications performance constraints and concerns.

JADS Subobjective 2-1-3. Assess the impact of ADS reliability, availability, and maintainability on T&E.

JADS Objective 2-2. Assess the critical constraints and concerns in ADS support systems for T&E. This objective was broken down into subobjectives.

JADS Subobjective 2-2-1. Assess the critical constraints and concerns regarding ADS data management and analysis systems.

JADS Subobjective 2-2-2. Assess the critical constraints and concerns regarding configuration management of ADS test assets.

JADS Objective 2-3. Develop and assess methodologies associated with ADS for T&E. (Subobjectives 2-3-1, 2-3-3, and 2-3-4 are not applicable to the ETE Test Phase 4.)

JADS Subobjective 2-3-2. Develop and assess methodologies associated with test execution and control for tests using ADS.

2.4 Phase 4 Methodology

2.4.1 Tactical Vignettes

The ETE Test team enhanced an unclassified, U.S. Army Training and Doctrine Command (TRADOC)-approved, 54-hour corps battlefield simulation (CBS) scenario by replicating an Iraqi corps rear area of operations in Iraq. Table 1 describes the five tactical vignettes created in Janus 6.88D; each vignette covered a six-hour period of the battle. Representative targets present in the 150 x 150 kilometer (km) Southwest Asia (SWA) terrain box were air defense artillery (ADA) sites, command and control sites, lines of communications (convoys), logistics bases, and concentrations of armor and artillery units.

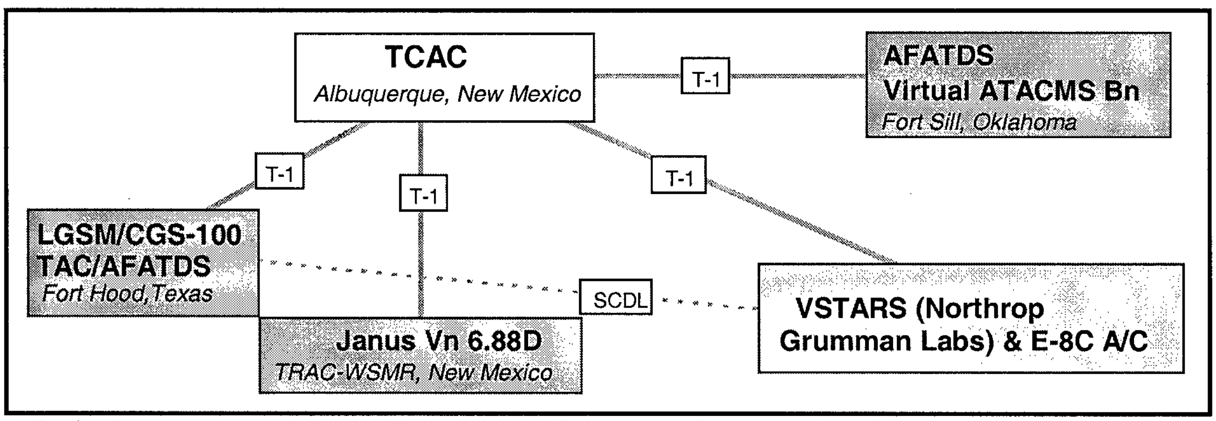
Table 1. Vignettes Used During ETE Testing

Vignette	Description	Number of Entities
1	Prehostility phase	9,897
2	Preemptive strikes	9,757
3	Hammurabi Division logistical operations	9,904
4	Commitment of the Hammurabi Division	9,781
5	General headquarters (GHQ) depots to corps and divisional logistical operations	9,950

2.4.2 Test Configuration

2.4.2.1 Phase 4 Synthetic Environment

Several components were required to create the ADS-enhanced live test environment used in Phase 4. Figure 3 provides an overview of the Phase 4 synthetic environment.



A/C = aircraft T-1 = digital carrier used to transmit a formatted digital signal at 1.544 megabits per second

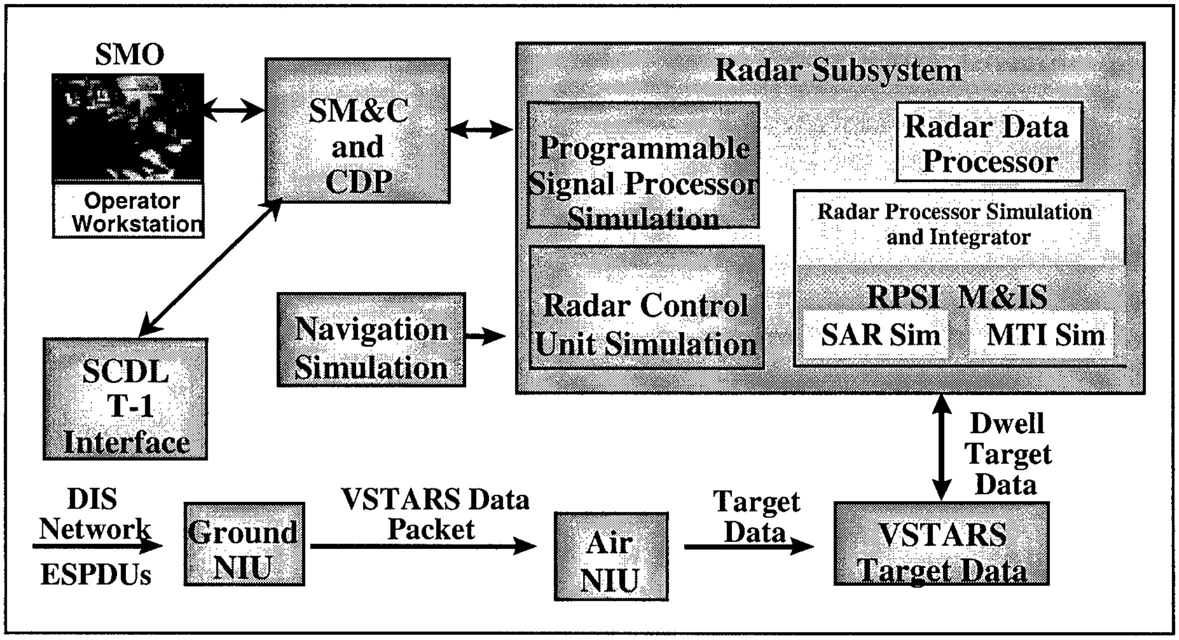
Figure 3. ETE Test Phase 4 Synthetic Environment

TRAC-WSMR provided the scenario feed for Phase 4 of the ETE Test using Janus 6.88D to generate the entities representing the threat's rear elements. The entities were sent, using entity state PDUs (ESPDUs), to the E-8C via the Test Control and Analysis Center (TCAC).

The TCAC in Albuquerque, New Mexico, provided test control. The JADS Network and Engineering (N&E) team monitored the health of the ETE Test network and ensured that adequate data flowed in support of the test.

The Joint STARS E-8C simulation, VSTARS, represented the Joint STARS E-8C in a laboratory environment. It consisted of a distributed interactive simulation network interface unit (NIU), an

RPSI that contained the two real-time radar simulations with necessary databases, and various simulations of E-8C processes. Figure 4 provides more information on the VSTARS architecture. VSTARS was operated at the Northrop Grumman Surveillance and Battle Management Systems facility in Melbourne, Florida.

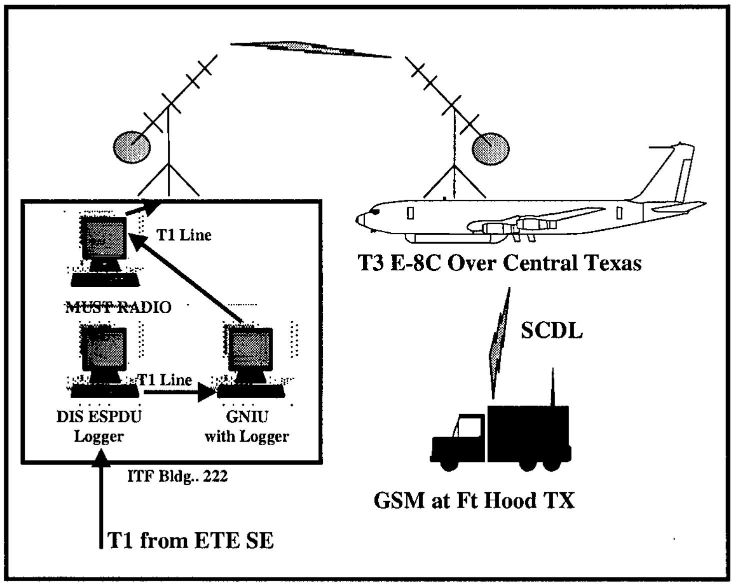


CDP - central data processor
MTI = moving target indicator
SM&C - system management and control
T-1 = digital carrier used to transmit a formatted digital signal at 1.544 megabits per second
M&IS - management and integration software
SAR = synthetic aperture radar
SMO - system management officer

Figure 4. VSTARS Architecture

The TAC, fire support command and control elements (provided by the AFATDS), and a LGSM were stationed at Fort Hood, Texas.

When the test was conducted in a live mode, an ADS-enhanced E-8C provided live, virtual, and mixed radar reports. The ADS-enhanced E-8C consisted of the T3 aircraft with the RPSI and the air network interface unit added as described in the Phase 3 report. Figure 5 provides more information on the ADS-enhanced E-8C configuration.



SE= synthetic environment T-1 = digital carrier used to transmit a formatted digital signal at 1.544 megabits per second

Figure 5. ADS-Enhanced E-8C Configuration

Communications among these C4I systems employed such doctrinally correct means as the CGS-100, a subsystem of the CAMPS, remote workstations, and AFATDS message traffic.

The AFATDS messages were transmitted between the AFATDS located at Fort Hood and the AFATDS located at Fort Sill using actual tactical protocols rather than DIS PDUs. Also, the SCDL messages were transmitted between VSTARS and the LGSM using a dedicated link, a special-purpose interface, and the actual tactical protocols.

The LGSM and TAC were represented by Bravo Company, 303d Military Intelligence Battalion. The AFATDS was manned by soldiers from the 4th Infantry Division (Mechanized).

The TAFSM simulation modeled the ATACMS battalion and sent the fire and detonate PDUs to the Janus 6.88D simulation. Janus then modeled the engagement results and reflected them in the synthetic environment (SE).

2.4.2.2 *Phase 4 Network*

Figures 6 and 7 provide a more detailed description of the ETE Test network.

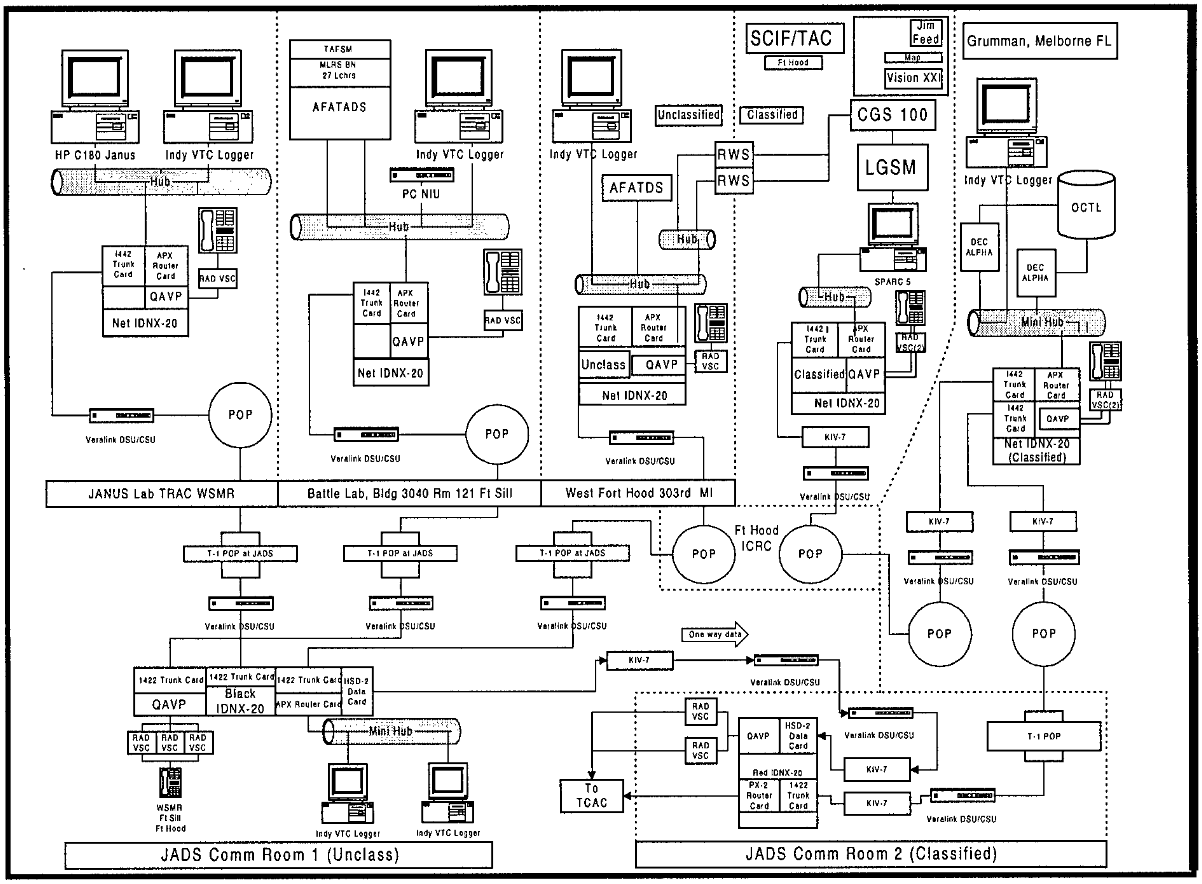


Figure 6. ETE Test Phase 4 Network Diagram (Virtual Phase)

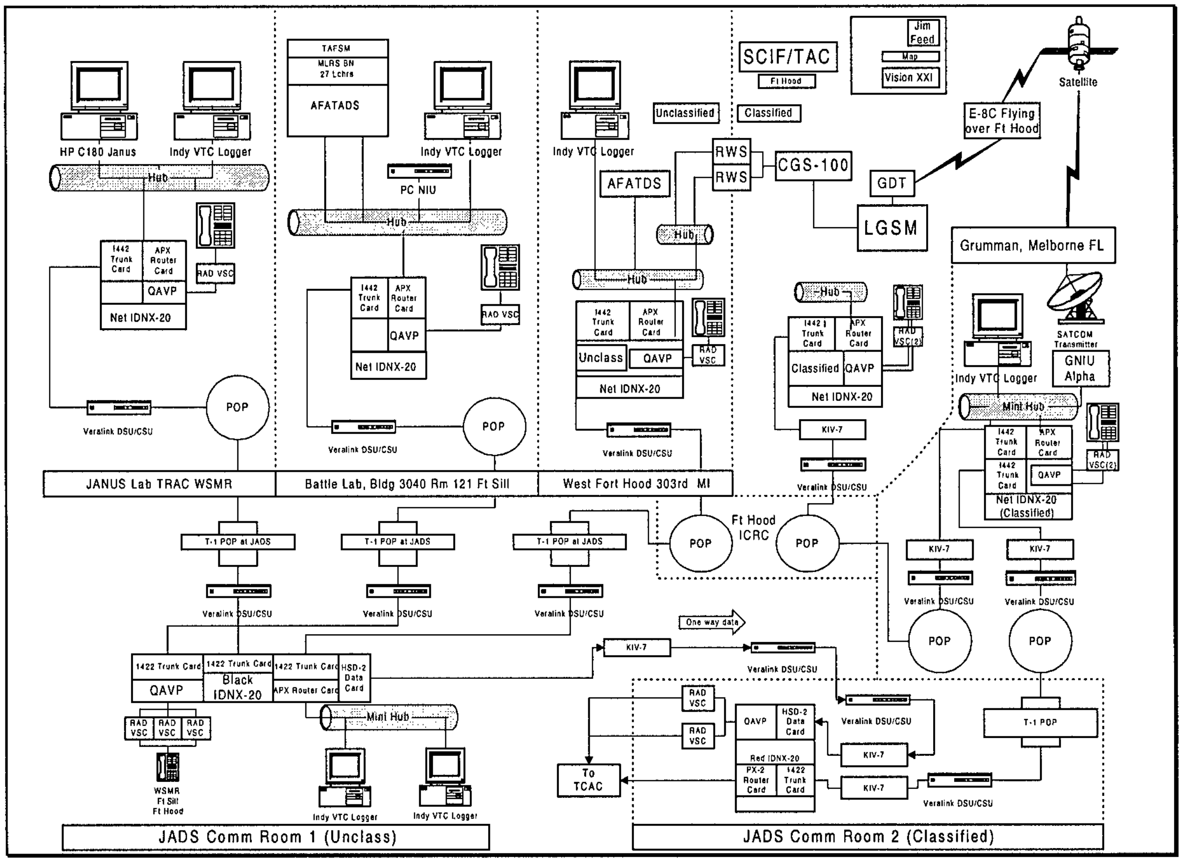


Figure 7. ETE Test Phase 4 Network Diagram

2.4.2.3 Test Control and Monitoring

During Phase 4, ETE Test and N&E team members performed test control from the TCAC. Test control consisted of three major areas -- network monitoring, communications, and test procedures.

The N&E team conducted network monitoring in the TCAC using hardware and software tools. The software consisted of commercial products and test-specific tools developed by JADS analyst/programmers. They used the following systems.

Silicon Graphics, Inc. (SGI) Indy - JADS logger
SGI Indy - time server
SGI Indigo - NetVisualyzer™
SUN SPARC 5 - SPECTRUM®
Line printers

JADS analyst/programmers developed the JADS logger. This software recorded all PDU traffic at individual sites. All nodes, with the exception of Fort Hood, had a JADS logger installed. The logger recorded the receipt of the PDU and time stamped it using an accurate time source. These data were used to analyze PDU transmission performance over the network.

JADS analyst/programmers also developed a time server that provided the accurate time source needed for the JADS logger. The time server was tied to a global positioning system (GPS) receiver located in the TCAC and provided time to all nodes with an accuracy of 100 microseconds. The software also contained monitoring tools to track the time servers performance over an 8-hour test period.

Cabletron SPECTRUM®, NetVisualizer™, and line printers were used to provide network monitoring. SPECTRUM® measured bandwidth utilization. This tool recorded the percentage of bandwidth used, as well as bandwidth loading on a network segment. NetVisualizer™ software displayed real-time bandwidth use in a rolling bar graph format for quick, visual reference. The line printers provided a printout of network router status. Any failure or high bit error rate resulted in a printout showing the problem and identity of the offending router.

Communication among the distributed ETE Test nodes was critical. The TCAC provided all needed communication systems. Dedicated phone circuits residing on the T-1 lines provided classified and unclassified service. The unclassified line allowed connectivity among the TCAC, Fort Hood, Fort Sill, and TRAC-WSMR. The classified line allowed connectivity among the TCAC, Fort Hood, and Northrop Grumman. These lines allowed the operator to select the desired site, lift the receiver, and connect directly to that site. The TCAC could select multiple sites for conference calls on these lines. In addition to these lines, the ETE Test team used an unclassified conference line to coordinate such test events as network checks and after-action debriefs. This line allowed up to ten participants to connect at one time.

Test procedures were required to provide effective control of all test nodes during test events. The test procedures were in checklist format, which provided for standardization among the distributed nodes. The network checklist was most critical and was used to initialize the network before the test. Other checklists included those used to start up hardware and software at individual nodes, as well as the checklist used by the TCAC test controller to start and stop the overall test.

2.5 Phase 4 Schedule

Figure 8 provides a schedule of the top-level tasks for Phase 4 of the ETE Test. Phase 4 testing proceeded as scheduled.

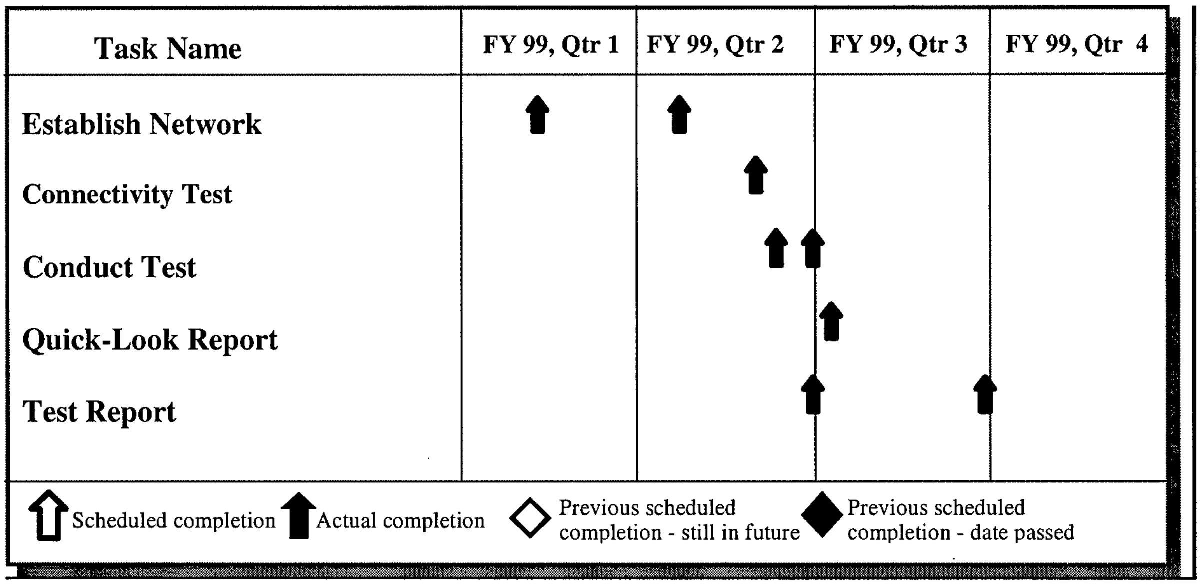


Figure 8. ETE Test Schedule

2.6 Phase 4 Costs

Appendix D of this report is a work breakdown structure covering the costs of all four phases of the ETE Test.

3.0 Phase 4 Execution Results

3.1 Risk Reduction Tests

3.1.1 15 March Trial

The Northrop Grumman VSTARS node was unable to establish SCDL during the 15 March trial because it was attempting to use the SCDL software developed for the aircraft. This software was incompatible with the laboratory computer workstations used during the trial. A tape of the radar reports derived from the Janus scenario was required and played at Fort Hood; the rest of the nodes received the live Janus feed. Tape playback problems occurred at Fort Hood resulting in cancellation of the trial. The SCDL problems at Northrop Grumman were resolved by using a previous version of the SCDL software modified to run under the Phase 4 test conditions. No nodes were required to run from tape for the remainder of the test.

3.1.2 16 March Trial

A successful laboratory trial was completed on 16 March with no major problems noted at any node.

3.1.3 17 March Trial

VSTARS problems were experienced during the 17 March trial. VSTARS was brought down to make software adjustments to keep entities on roads. This was required because an earlier version of the SCDL software was used as discussed above. VSTARS crashed later in the trial because of a disk usage problem. These problems were resolved before the end of the trial, and all nodes were prepared for the first ETE Test live flight on 19 March.

3.1.4 19 March Live Flight

During the 19 March live flight, communication problems between the TCAC and the E-8C resulted in the desired scenario start time being unclear. Janus and TAFSM were started too soon and were stopped until the radar simulation was functioning properly on board the E-8C. Once the radar simulation was running, the simulations were restarted and start-up data were uploaded. When the aircraft arrived on station, a SCDL uplink could not initially be established. Numerous corrective measures were attempted at Fort Hood and on board the E-8C. Following a reboot of certain SCDL processes on the E-8C, the SCDL problem was resolved. Problems with SCDL, along with intermittent satellite outages, continued throughout the flight. Despite the problems with SCDL and the satellite link, the 19 March live flight accomplished all the verification, validation, and test objectives planned for the flight. The 19 March flight was a successful implementation of an ADS-enhanced live test environment and was notable for four key events.

1. The Joint STARS system incorporating the JADS capability exhibited normal in-flight operation without any noticeable performance degradation.

2. Scenario data were received from White Sands via SATCOM and displayed in near real time on the aircraft.
3. The scenario data, as reflected in the radar reports, were transmitted through the SCDL link to the GSM at Fort Hood.
4. Radar reports that contained live, virtual, and mixed areas within the ground reference coverage area (GRCA) were generated and displayed on the ATWSs and GSM.

3.2 Operational Testing

3.2.1 24 March Trial

The 24 March trial was a laboratory trial that encountered difficulties with the VSTARS synthetic aperture radar (SAR) simulation. The problem was a reoccurrence of the disk problem that occurred during the 17 March trial. The equipment was repaired before the next laboratory trial, and caused no further test delays or stoppages. The problem did prevent the availability of SARs during the trial causing VSTARS to operate in a degraded moving target indicator (MTI)-only mode. All other nodes executed the 24 March trial without any problems.

3.2.2 25 March Live Flight

For the 25 March live flight, excellent communication and coordination among the TCAC, Northrop Grumman lab, and the E-8C resulted in a smooth test start-up and transition. The test mission accomplished the majority of the verification, validation, and test objectives planned for the flight. Because of E-8C radar problems experienced near the end of the flight, the mixed radar portion of the test could not be evaluated. Resolution of the radar problems occupied the remainder of the available station time, and the aircraft was required to depart the Fort Hood area. On the way back, all components of the radar and radar simulation were rebooted and all components functioned normally.

3.2.3 29 March Trial

The 29 March trial was very successful. No nodes reported major problems and the SAR simulation (sim) hardware problem at Grumman from the 24 March trial was resolved. In addition, the redundancy added to the network following the Phase 2 test proved to be a worthwhile addition. The T-1 line between the TCAC and Grumman went out for a short while, but the test was not impacted as PDUs were routed to Northrop Grumman from the TCAC via Fort Hood.

Following the trial on 29 March, it was determined that there were problems with the Northrop Grumman log file for the trials on 25 and 29 March. Although the logger received nearly all the PDUs, the log files showed large PDU losses. N&E personnel checked the loggers and log files and found no problems. It was later determined that compiling work accomplished during the test may have affected the processing capability of the computer and caused the PDU losses. For the 30 March trial, it was decided that no compiling work would be done during the trial.

3.2.4 30 March Trial

The trial on 30 March was also very successful. No nodes reported any problems, and there were no test stoppages or delays. The test was stopped one hour early to allow for analysis of the Northrop Grumman log file. The log file was complete, and it was determined that the logger was functioning properly.

3.2.5 31 March Live Flight

The live flight on 31 March was the most successful of the three ETE Test flights. There were no communication problems, and no Janus restarts were required. SATCOM and SCDL were both briefly postponed. Following these delays, the test ran very smoothly. The E-8C flew an extra hour on station allowing for extra test time. Virtual only, live only, and a mixed area were displayed throughout the on-station period with the mixed area containing both live and virtual ground vehicles.

4.0 Analysis of Test Objectives

During the operational test portion of Phase 4 of the ETE Test, JADS analysts collected information to address the issues, JADS objectives, and test measures as outlined in the JADS Program Test Plan (PTP) and the ETE Test Data Management and Analysis Plan (DMAP). Only those subobjectives and measures evaluated using Phase 4 results are discussed.

4.1 JADS Issue 1. What is the present utility of ADS, including DIS, for T&E?

This objective determines the extent to which ADS technology can support the T&E of current and future C4ISR systems.

4.1.1 JADS Objective 1-1. Assess the validity of data from tests utilizing ADS, including DIS, during test execution.

During Phase 4, the ETE Test team examined the validity of data from an ADS configuration incorporating the VSTARS simulation, Janus simulation, and other components into a C4ISR architecture.

JADS Measure 1-1-0-1. Degree to which ADS provides valid system under test (SUT) data.

JADS Measure 1-1-0-2. Percentage of ADS data which are valid (data supporting test measures which are timely, accurate, reliable, and otherwise faithfully represent real-world systems data).

JADS Measure 1-1-0-3. Degree to which test participants were able to distinguish among virtual, constructive and live targets.

JADS Measure 1-1-0-4. Degree to which test actions were impacted because of the ability to distinguish among virtual, constructive and live targets.

These four test questions gauge the ability of an ADS-enhanced live test environment to provide valid data for a C4ISR system under test. The first measure addresses the validity of the SUT output data that form the data elements for evaluating SUT measures. The second measure provides an assessment of the input data provided to the SUT by the ADS-enhanced live test environment. The third and fourth measures address the impact on testing of the various targets provided by an ADS-enhanced live test environment.

These measures were primarily addressed through the implementation of the ETE Test V&V Plan, and the Phase 3 V&V and system integration tests. Since JADS is a DoD-sponsored joint test, the basis for all V&V activities was the DIS Nine-Step VV&A Process Model and its accompanying *Recommended Practice for Distributed Interactive Simulation -- Verification, Validation, and Accreditation* (draft-21 May 1996). Figure 9 provides an overview of the VV&A process model. Note that this model has been extensively discussed with numerous members of the DIS modeling and simulation (M&S) community, has been generally accepted by V&V practitioners, and is currently being balloted as a standard.

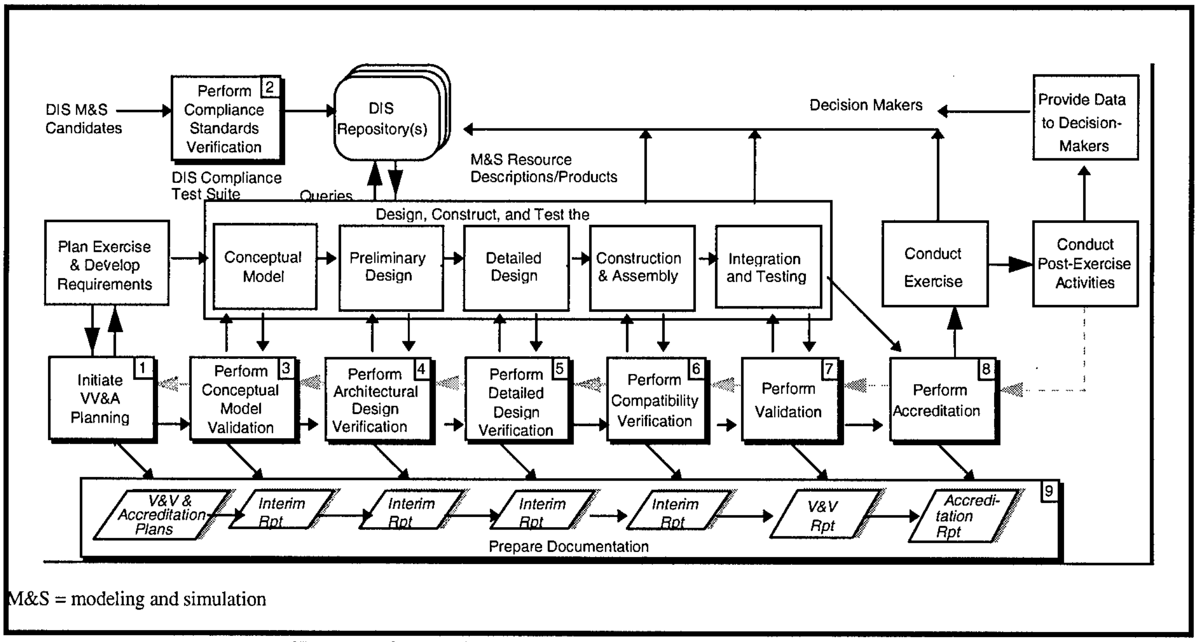


Figure 9. DIS Nine-Step VV&A Process Model

The ETE Test VV&A represented a tailoring and implementation of the nine-step process to a multiservice test of a major system, Joint STARS, augmented with ADS. The tailored ETE Test process model used is described in the V&V reports for the ETE Test. (Available from JADS, 2050A 2nd Street SE, Kirtland Air Force Base, New Mexico, 87117-5522. After 1 March 2000 refer requests to HQ AFOTEC/HO, 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 or SAIC Technical Library, 2001 North Beauregard St. Suite 80, Alexandria, Virginia 22311.)

The results from implementing the ETE Test V&V process model for the Phase 4 ADS configuration are detailed in the ETE Test V&V reports and are summarized as follows.

- **Verification of Janus 6.88D**
  - Janus 6.88D was capable of simulating at least 5000 entities (actually 9999 entities) with at least twenty-five percent moving.
  - Janus 6.88D operators were capable of fully interacting with a scenario while it was running. In particular, the Janus site representative interacted with the scenario after several ATACMS impacts by altering the behavior of the surviving entities within the immediate area of the impact.
  - Janus 6.88D accepted and processed scenarios with a duration longer than eight hours.
  - Janus 6.88D was capable of proceeding at a pace representative of near real time.
  - Janus 6.88D was capable of utilizing scenarios conducted upon terrain representing a simulation area of at least 170 km by 170 km.

- **Verification of the RPSI**

  - The RPSI received and integrated virtual data from the Phase 4 ADS-enhanced live test environments.
  - The RPSI operated in three modes: live only, mixed live and virtual, and virtual only using the standard Joint STARS MTI message format.
  - The radar timeline was not impacted by the MTI simulation.
  - The RPSI processed parameter data in the same format as Joint STARS.
  - The RPSI displayed live SARs in live areas of interest and virtual SARs in virtual areas using the standard Joint STARS SAR message format. Because of a software error, the RPSI did not display virtual SARs in a mixed area. Instead, it displayed live SARs in the mixed area. This problem had previously existed in the laboratory version of the RPSI that was integrated into VSTARS. The correction was simple and previously tested but involved a change to the JDS 07_006+ software build that the JTF had already approved for flight testing on 15 March 1999. Since the aircraft would not be available for additional testing prior to the 19 March flight test, and the feature would not be used during the conduct of the Phase 4 test, it was decided by the ETE Team lead to not correct the JDS 07_006+ software build.
  - The RPSI permitted all the installed operator workstation software to function without abnormal fault messages.

- **Verification of compliance standards (DIS step 2).** It was verified that the PDUs emitted by each simulation adhered to the prescribed format.

  - It was verified that Janus 6.88D issued DIS 2.0.4 ESPDUs that conformed in content and format with the DIS 2.0.4 standards as amended by JADS. (JADS modified the ESPDU time-stamp format from time passed since the beginning of the current hour to milliseconds since the beginning of the vignette. This allowed testers to trace an ESPDU back to a discrete event that occurred within the Janus vignette.)
  - The AFATDS located at Fort Hood communicated directly with the AFATDS at Fort Sill using standard AFATDS message traffic instead of DIS PDUs. The AFATDS located at Fort Sill than communicated through a DIS NIU with TAFSM using DIS PDUs.

- **Verification of compatibility (DIS step 6).** It was verified that the modeling and simulation (M&S) components exchanged data and interacted appropriately with one another; that individual components correctly used the common data (e.g., terrain, weather) to generate their portion of the synthetic environment, and that the overall implementation was adequate to address the exercise requirements. It was also verified that the network allowed transfer of information among the components without corruption and the individual components shared a common perspective of the virtual reality produced by the exercise.

  - It was verified that Janus 6.88D received each ESPDU, fire PDU, and detonate PDU issued to it by the network and took the appropriate action as dictated by the PDU. In particular, Janus correctly identified ATACMS launches initiated by Fort Sill that were outside the scenario terrain box.

- It was verified that TAFSM accepted artillery missions using DIS PDUs and that TAFSM issued a fire and detonate PDU whenever an ATACMS missile was fired and subsequently detonated.

- **Validation of the ETE Test Phase 4 synthetic environment (SE) (DIS Step 7).**

  - It was validated that the integrated simulations were adequate to satisfy the ETE Test requirements such that the behavior and performance of the SE mapped sufficiently to real-world counterparts for the specific ETE Test application. The conclusion that the ETE Test SE was a realistic representation of the real world was based on structured interviews with the RPSI, LGSM, and TAC operator subject matter experts (SME) participating in the test.
  - It was specifically validated that Janus 6.88D represented vehicle behavior to the degree detectable by the Joint STARS, as judged by Joint STARS operator SMEs viewing vehicle movement presented by the Joint STARS operator workstation. Realistic vehicle behavior was achieved after correcting an anomaly observed during Phase 2 ETE risk reduction testing.
    - The anomaly consisted of portions of convoys missing turns and wandering off into the desert. The lost portion of the convoy would then jump back into formation after a period of time and resume normal movement.
    - It was determined that this was caused by Janus not sending change of state ESPDUs in a timely fashion. Within Janus, or any other DIS compliant simulation, ESPDUs are sent for any change of state (starting, stopping, turning, or changing speed beyond preset limits) in addition to the normal heartbeat ESPDUs for stationary entities. When Janus did not send the change of state ESPDUs in a timely fashion, VSTARS continued to move the vehicle in a straight line based upon the last received ESPDU.
    - The delay was caused by the method that Janus uses to send ESPDUs. Janus cycles through the list of entities at a rate set by the operator and sends either a heartbeat ESPDU or a change of state ESPDU as appropriate. Because there were nearly 10,000 entities represented within Janus, it was necessary to set the cyclic rate at a low enough value so that it took Janus nearly 15 minutes to issue the 10,000 ESPDUs. The solution was to turn off the heartbeat prior to the beginning of entity movement. This allowed adjustment of the cyclic rate so that Janus would check the 10,000 entities every 10 seconds and issue only change of state ESPDUs. This reduced the delay in sending the change of state PDUs and the anomaly was no longer detectable.
  - For the RPSI validation, several of the operators who had participated in the modified Turing test during Phase 2 also performed the SIT. They were asked to compare RPSI performance with the modified Turing test and Joint STARS. Slight differences were noted, but test participants still characterized the RPSI as having the same capabilities and limitations as Joint STARS. They could not identify any RPSI process or function that limited their ability to perform their mission/job or altered their approach to their mission/job. Results demonstrated a close correspondence between the RPSI and Joint STARS.

Conclusion for JADS Measure 1-1-0-1. The Phase 4 ADS configuration produced valid SUT data and did not affect or hamper the functionality of the actual Joint STARS radar. The credibility of the SUT data was enhanced by the use of actual operational hardware wherever possible (e.g., ATWS, LGSM, AFATDS) with actual trained operators. The RPSI was designed so that the only simulated portion was the simulation of the MTI and SAR radar modes within the radar subsystem; everything else was either integration code or actual E-8C system code. The inputs into the RPSI, except for the target data, were normal inputs into the real radar processor, and the outputs were the actual radar reports. The radar simulations were parallel processes with the radar when live and virtual were mixed and solved the radar equations in order to achieve the required fidelity.

Conclusion for JADS Measure 1-1-0-2. Under normal operations, all input data (radar reports) provided to the SUT (Joint STARS) by the ADS-enhanced live test environment were valid. Network performance and reliability in delivering data to the SUT are analyzed under JADS Objective 2-1.

Since the Phase 4 ADS configuration produced valid SUT data, this configuration is usable for Joint STARS DT&E and OT&E.

Conclusion for JADS Measure 1-1-0-3. During the Phase 4 operational testing (OT), all GSM operators and JADS observers were able to easily distinguish between the live areas and the virtual areas. Though the size, color, contrast, and movement of the MTI radar reports were indistinguishable, the quantity of MTI dots and the clutter associated with them was clearly distinguishable. The primary reason for this was because the vignettes used by JADS depicted a tactical scenario, while the live areas consisted of civilian traffic in and around Fort Hood (Killeen, Texas). The operators were familiar with the live area and were able to easily determine major roads and highways around Fort Hood.

If the live and virtual areas had been of the same type (tactical, administrative), it would have been much more difficult to distinguish between the two. Within the mixed area, it was impossible to distinguish between the live and virtual entities based upon size, color, contrast and movement. Since the tactical scenario took place in Iraq, and the maps only showed Iraqi roads, one could assume that the vehicles moving on the mapped road structure were virtual. However, there was no way to tell positively that this was the case, and those vehicles not moving on the mapped roads could easily be off-road traffic moving about the desert or vehicles moving on unmapped roads.

Conclusion for JADS Measure 1-1-0-4. The operators in the GSM provided intelligence to the TAC either because the TAC requested it or because the operators noticed something significant and reported it to the TAC. Since the TAC officer in charge (OIC) was only concerned about the virtual entities, information regarding live entities was not requested. Similarly, since the operators knew that the TAC was only interested in simulated entities, they did not request radar reports for live entities on their own. The only times when operators performed their regular operator functions on live assets were when the testers (JADS) prompted them. As a result, the live entities did not play any role in the GSM to TAC relationship. When the operators did perform operator functions on live or simulated assets, their actions were exactly the same for each. The method of requesting a SAR, different types of MTI, or tracking vehicles/convoys was exactly the same.

Utility for DT&E

Though not specifically tested in Phase 4, the ADS-enhanced live test environment can be used to conduct developmental testing of all nonradar subsystems that comprise Joint STARS, given that the RPSI is an accurate representation of the radar. Obviously, the RPSI can not be used to conduct developmental testing of the radar subsystem.

Most developmental testing of product improvements require test flights prior to acceptance. As an example, one of the features of the workstation used on the E-8C is an automatic tracker (A-tracker). The A-tracker uses radar reports and, when initiated, will automatically track a designated formation providing bearing, speed and number of vehicles. Prior to the creation of the ADS-enhanced live test environment it was necessary to either have a functioning radar (test flight) or a recording of a functioning radar in order to test the A-tracker. Test cases were basically limited to those that could be achieved at Eglin Air Force Base, Florida, with a minimal number of vehicles traveling under peacetime safety restrictions.

Use of the ADS-enhanced live test environment allows the tester to repeat the live test described above, and at the same time, conduct ADS-enhanced tests of more complex scenarios that are required but impossible to achieve at Eglin AFB. The A-tracker could be tested under operationally realistic conditions, closing the gap between specification testing and operational performance.

Utility for OT&E

The utility of this configuration for Joint STARS OT&E was evaluated by determining which measures from the Joint STARS Multiservice Operational Test and Evaluation (MOT&E) Plan[3] could be supported. Appendix B (available under separate cover from JADS JTF) identifies which Joint STARS MOT&E measures could be evaluated using the Phase 4 ADS configuration. For comparison, the measures that were addressed during the contingency operations[4] were also identified.

[3] *Joint Surveillance Target Attack Radar System (Joint STARS) Multiservice Operational Test and Evaluation (MOT&E) Plan*, Air Force Operational Test and Evaluation Center, Kirtland Air Force Base, New Mexico, 21 February 1995.

[4] *Joint Surveillance Target Attack Radar System (Joint STARS) Contingency Operations Test and Evaluation (COT&E) Plan*, Air Force Operational Test and Evaluation Center, Kirtland Air Force Base, New Mexico, 1 December 1995.

Results in Appendix B are summarized as follows.

- The Phase 4 ADS configuration evaluated 15 out of 45 effectiveness measures of performance (MOP) (including two MOPs not evaluated during the Joint STARS contingency operations test and evaluation) and all eight measures of effectiveness (MOE) using the actual components of the system.

- If additional elements (simulated or real) were added to the Phase 4 ADS configuration it could be used to fully evaluate 18 of the 18 MOPs supporting critical operational issue (COI)-1. *(Does Joint STARS perform its tactical battlefield surveillance mission?)*

- If additional elements (simulated or real) were added to the Phase 4 ADS configuration it could be used to fully evaluate 24 of the 24 MOPs supporting COI-2. (*Does Joint STARS support the execution of attacks against detected targets*?)

- The Phase 4 ADS configuration can support evaluation of the single measure of effectiveness (MOE) for COI-3 (*Does Joint STARS provide timely and accurate information to support battlefield management and target selection*?) and both MOPs for COI-4. *(Can the Joint STARS system be sustained in an operational environment?)*

- If additional elements (simulated or real) were added to the Phase 4 ADS configuration it could be used to support the evaluation of 17 of the 17 additional Joint STARS effectiveness measures.

- Since the Phase 4 ADS configuration utilizes an actual GSM, 27 out of 27 suitability MOPs involving the GSM and the E-8C could be evaluated.

- The Phase 4 ADS configuration could support the evaluation of all 8 human factors measures.

- The Phase 4 ADS configuration could not support the evaluation of any of the E-8C software evaluation measures (0 of 6).

In summary, the Phase 4 ADS configuration evaluated the same measures as the Phase 2 ADS configuration using the actual components of the system. However, if additional elements (simulated or real) were added to the Phase 4 ADS configuration, it could evaluate all 45 effectiveness MOPs (including two MOPs not evaluated during the contingency operations) and all 8 effectiveness MOEs. Furthermore, the augmented Phase 4 ADS configuration could be used to evaluate the GSM and E-8C suitability MOPs (27 out of 27 suitability MOPs), all of the human factors MOPs, and all of the software MOPs.

In addition, for those MOPs and MOEs that address Joint STARS effectiveness in an operational environment, the Phase 4 ADS configuration provided a more complete and realistic targeting environment and the ability to engage targets as desired.

4.1.2 JADS Objective 1-2. Assess the benefits of using ADS, including DIS, in T&E.

4.1.2.1 JADS Subobjective 1-2-1. Assess ADS capability to support the early phases of the acquisition process.

JADS Measure 1-2-1-4. Degree to which ADS can improve early operational assessments.

One of the common shortcomings of operational testing for C4I systems is the inability to conduct a robust initial operational test and evaluation (IOT&E) of the complete systems of systems. This shortcoming all too often results in the execution of a final operational evaluation (OPEVAL) that uncovers significant problems with the system under test. These problems can limit the tester in evaluating the system's operational effectiveness and suitability. In severe cases major portions or even the entire test event must be rescheduled and repeated after deficiencies have been corrected.

ADS can provide a useful tool for the tester in support of early operational testing. ADS can bring together the components of a complex C4I system of systems for testing using a mix of actual and simulated assets. This capability allows for earlier testing which may identify potential issues that would impact the conduct or the results of an OPEVAL.

4.1.2.2 JADS Subobjective 1-2-2. Assess ADS capability to support T&E planning and test rehearsal.

JADS Measure 1-2-2-1. Degree to which a test concept/design can be improved through experimentation using an ADS environment.

JADS Measure 1-2-2-2 Degree to which a test concept/design is impacted by ADS.

ADS has the ability to greatly impact test concept and design allowing the test designer to surmount such conventional testing shortfalls as inadequate numbers of friendly and threat systems, safety, range availability, and environmental conditions. Simulations can adequately depict these conditions and allow the testers to adequately test concepts that they might not be able to otherwise test. Since an ADS-enhanced live test environment does not require massive coordination of soldiers and movement, it is much easier to make changes to the test concept and record the results. The ETE Test configuration was established specifically for the ETE Test concept. Similarly, other test configurations could be established to expand on the ETE Test concept or to test new ones.

There are some negative impacts on test concept and design using an ADS-enhanced live test environment. First, technical expertise is required to establish, maintain, and troubleshoot ADS-related problems. These include personnel trained to operate the different simulations as well as to maintain the network linking different sites. Second, establishing an ADS configuration has a substantial up-front cost. Finally, meticulous coordination is required to schedule and execute an ADS test, since problems at one node will almost certainly affect the execution of the test concept at other nodes. For example, VSTARS malfunctions on several days greatly diminished our ability to test and record actions at the TAC, consequently affecting the TAC's ability to identify targets and use ATACMS properly to destroy those targets.

Testers must evaluate the risks and rewards of the test concept and design before testing. Though ADS allows for a more robust test design, the cost, technical expertise, and coordination required may make it very difficult or impractical.

JADS Measure 1-2-2-4. Degree to which pretest exercise of data reduction and analysis routines using ADS improved test preparations.

JADS Measure 1-2-2-7. Degree to which data reduction and analysis routines can be improved through experimentation using an ADS environment.

JADS Measure 1-2-2-8. Degree to which data reduction and analysis routines are impacted by incorporating ADS as part of the test concept/design.

These measures evaluated the impact of ADS technology on data reduction and analysis routines. In support of these test questions, the ETE Test analysts conducted interviews with test team members involved in data reduction and analysis during the Phase 4 operational test and test rehearsals.

The Phase 4 data reduction and analysis methodology were based in large part on procedures successfully used in earlier JADS tests, with the exception of the reduction and analysis of the SATCOM data. Procedures used during the functionality and integration (FI) and risk reduction tests, as well as during the Phase 4 operational test (OT), were basically unchanged from those used previously. During Phase 3, pretest exercises and experimentation were accomplished on the data reduction and analysis required for the SATCOM data in order to determine the necessary changes to the test configuration. Based on these pretest activities, the Janus scenarios were adjusted to ensure that the link capacity was not exceeded. The incorporation of the E-8C into the ETE Test environment also impacted the data reduction and analysis methodology. In particular, the conversion of the data from the ground NIU at Northrop Grumman and the data from the logging software on the E-8C into a usable format required a great deal of manipulation by the JADS analyst programmers.

Data reduction and analysis activities in Phase 4 were aided by the use of the JADS Analysis Toolbox. The routines in the toolbox were also useful in analyzing the SATCOM link data once the data were manipulated and converted into a format similar to that of the PDUs.

Developed over the course of earlier JADS tests, the toolbox is a set of software routines written in the C++ programming language and integrated into a single user interface. The toolbox can be employed to develop tables and plots of PDU data in near real time. After the test, toolbox users can replay or get selected data in a text-readable format from JADS log files and obtain plots and tables of PDU statistics. The PDU statistics, in turn, include the number of PDUs received, the number of each type of PDU received, and the rate at which PDUs are being received. An important point is that the ETE Test log files were larger than earlier JADS test log files.

Modifications were made to the toolbox software to minimize the impact of the size of the log files on file access time as well as on the amount of memory needed for calculations. (For further information on the JADS Analysis Toolbox, contact the JADS JTF or the JADS Web site at http://www.jads.abq.com where it will be available until March 2001. After that it will be available at HQ AFOTEC/HO, 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 or SAIC Technical Library, 2001 North Beauregard St. Suite 800, Alexandria, Virginia 22311.)

Table 2 describes the estimated number of hours spent on rehearsing data reduction and analysis procedures for the Phase 4 risk reduction tests and OT. The times presented in Table 2 do not include time spent on either data collection or report writing.

Table 2. Time Spent on Pretest Data Reduction and Analysis Rehearsals

Data Type	Risk Reduction Testing	Operational Testing
PDU Data	12 hrs	16 hrs
Latency	12 hrs	16 hrs
Network Availability	6 hrs	8 hrs
ADS System Availability	6 hrs	8 hrs
Bandwidth	3 hrs	4 hrs
Packet Rate	2 hrs	3 hrs
Other OT Test Measures	20 hrs	25 hrs

The ETE Test Phase 4 also demonstrated the unique advantages of an ADS-enhanced live test environment with respect to data reduction and analysis processes.

- For both ADS and conventional tests, these routines are typically developed prior to the actual test events. For non-ADS tests, actual test assets (i.e., flight time) may need to be expended in order to produce the data needed to test these routines. In contrast, the JADS analysts were able to exercise their data reduction and analysis routines using data from the FI and risk reduction tests accomplished prior to Phase 4 OT testing. This early availability of test data enabled the analysts to check out and refine these procedures and prevented the loss of critical test data from the actual Phase 4 OT test.

- If an ADS test team emphasizes the early exercise of data reduction and analysis routines during pretest rehearsals, it can reduce or eliminate the loss of critical data and expenditure of valuable test assets during subsequent actual testing. Even the addition of a new type of data (i.e., SATCOM link data) can be smoothly managed by relying on the data reduction analysis methodology and routines that have been successful in the past.

– The networked nature of an ADS-enhanced live test environment provides a built-in means to support data management. During the risk reduction tests prior to Phase 4 operational testing, the ETE Test team took advantage of this capability and was able to speed the transport of test data from the nodes to a central collection and analysis point.

JADS Measure 1-2-2-5. Degree to which ADS can be used for tactics development prior to test execution.

JADS Measure 1-2-2-9. Degree to which tactics development can be improved by experimentation in an ADS environment.

These measures determined if the techniques and procedures used by the test participants to obtain and disseminate information on target enemy forces could be enhanced in any way using an ADS-enhanced live test environment. In a broader context, JADS analysts wanted to determine if the ADS test environment could be used to correct, refine, and change tactics, techniques, and/or procedures prior to exercising a live test. During the previous tests (Phase 2 rehearsal, Phase 2 OT, and Phase 4 rehearsal), the TAC OIC was able to experiment with employing the ATACMS based on intelligence from different sources (GSM MTI, GSM SAR, Joint Exercise Support System Intelligence Module [JIM] feeds) against different types of targets (convoys, assembly areas, logistical sites, etc.). With increased test time and experimentation, the TAC OIC was able to refine tactics and confirm its effectiveness during the Phase 4 OT. This experimentation clearly improved the ability to select the right types of targets based on the right source of intelligence for those targets in order to maximize the effectiveness of the ATACMS.

The increased test time provided by an ADS-enhanced live test environment appears valuable in allowing C4ISR system operators and end users to confirm and refine current tactics and to experiment with "what if" scenarios and new tactics.

JADS Measure 1-2-2-6. Determine the impact of ADS on test planning and rehearsal costs.

The use of ADS in test execution and test rehearsal events can impact overall test program cost. This impact on cost, as with any test program, must be considered along with the benefits. The possible increase in cost to a program from the use of ADS can be justified if acceptable reductions in risk or schedule can be achieved. Risk reduction can be achieved using ADS by allowing a tester to test and exercise a complex system of systems early in that program's life. ADS can provide a tester with the chance to rehearse a complex test, with all players in a distributed manner prior to bringing actual assets together for an expensive test event. With many conventional tests, the complex systems are not tested together until IOT&E. If problems are encountered in this late stage, it is difficult and very expensive to make changes. The earlier problems are found, the less risk to both program cost and schedule. ADS, in most cases, will not reduce the cost of testing, but it is a means for providing a more robust test event that can minimize cost and schedule overruns.

4.1.2.3 JADS Subobjective 1-2-3. Assess ADS capability to support T&E execution.

JADS Measure 1-2-3-1. Degree to which ADS can add test articles to test execution.

JADS Measure 1-2-3-8. Degree to which ADS can provide for more representative force levels.

JADS Measure 1-2-3-17. Degree to which ADS can increase the number of simulation entities.

JADS Measure 1-2-3-28. Degree to which ADS overcomes the use of improper threats used in traditional T&E.

Conventional T&E typically suffers from an inadequate number of entities. Typical tests may have to be conducted in conjunction with training missions in order to acquire possibly hundreds of assets. However, testers will then have only minimal control over test specifics and must base their test on the training scenario being executed. In many cases, the training scenario will not include the desired threats, leading to the improper use of threats for the test.

In contrast, Table 3 shows that the Janus simulation provided thousands of entities for each vignette in Phase 4; entities created specifically to represent realistic threats for the test.

Phase 4 results imply the following benefits of ADS-based testing.

- An ADS-enhanced live test environment using validated simulations can provide more realistic threats and force levels than those offered by conventional tests, i.e., threats/levels otherwise unavailable because of cost restrictions, unobtainable threats, etc.

- C4ISR system testers can tailor the simulation entities operating in the ADS environment to closely reflect the forces expected in operational theaters, thus further increasing the relevance of the collected test data.

- ADS allows testers to have more control over the specific aspects of the scenarios of interest and to expand their test concept and design. A typical constraint to test concept development is the number and types of units readily available for a test. For example, a conventional test may require the use of a battalion, but because of a prior commitment or cost these personnel may not be available. In contrast, ADS allows testers to create a virtual battalion and to test their concepts with a minimum number of personnel and equipment.

Table 3. Entity Count Per Vignette

Vignette	Number of Entities
2	9,757
3	9,904
4	9,781
5	9,950

JADS Measure 1-2-3-3. Degree to which ADS overcomes performance restrictions.

ADS is helpful in simulating maneuver scenarios that overcome shortfalls associated with traditional testing. This technology increases test robustness by providing the capability for adding large numbers of assets. ADS simulations can depict such unsafe conditions as convoy vehicles driving across rugged or restricted terrain under wartime conditions. Finally, this technology frees the tester from the constraints of environmental restrictions. Without the benefits of ADS-enhanced testing, it would be almost impossible to instrument and maneuver a corps-size element.

JADS Measure 1-2-3-4. Degree to which ADS overcomes the traditional T&E shortfall of insufficient battlespace.

ADS technology can eliminate the conventional testing disadvantage of insufficient battlespace. The largest tests conducted by the Army, comparable to the scenarios tested by the ETE Test team, are accomplished at the National Training Center (NTC). These tests are executed in conjunction with NTC using a maximum battlespace of about 100 square kilometers (km^2). The results show the great increase in battlespace exhibited by the Phase 4 test over traditional testing where an additional 50 km^2 were added to the battlespace. In addition, the battlespace of 150 km^2 used by the ETE Test team is far from the maximum that ADS is capable of supporting. This battlespace was picked for its applicability to the scenarios used during the Phase 4 test and could be greatly expanded if necessary.

JADS Measure 1-2-3-7. Degree to which ADS overcomes the lack of systems for interoperability testing associated with traditional T&E.

JADS Measure 1-2-3-12. Degree to which ADS can increase the number of systems for compatibility evaluation.

There were many interoperability problems among the fielded real systems used in the ETE Test. Up to the time that the ETE Test occurred, the TAC had never had the opportunity to accomplish interoperability testing under tactical conditions in a doctrinally correct manner. During the ETE Test, several systems were able to operate together and function as intended during combat-like conditions. Specifically, the LGSM was electronically linked to the ASAS workstations located within the TAC and provided a complete operational picture of an enemy corps rear area. In addition, the ASAS workstations were electronically linked to the AFATDS terminal and electronically passed fire missions for prosecution by the ATACMS. Observer SMEs from III Corps intelligence community stated that this was the first time they had seen all these systems linked and operating as they should during a conflict.

JADS Measure 1-2-3-9. Degree to which ADS increases the number of test events.

Using ADS, testers can replicate a test, as well as test for longer periods of time. During the Phase 4 test, the ETE Test team was able to test for 50 hours over a period of eight test days. A test using real assets of similar duration would be very expensive and probably even impossible.

JADS Measure 1-2-3-16. Degree to which ADS can overcome test area time/availability restrictions.

ADS technology can overcome the shortfalls of limited test area time and availability often associated with traditional testing. Conventional testing requires the use of live ranges, soldiers and equipment to depict realistic conditions for testing and training. Typically, these resources have to be scheduled far in advance and are available only for a limited time or usage. An ADS-enhanced test can surmount this shortcoming by using and linking simulations as a substitute for the necessary resources. For example, the ETE Phase 4 OT used vignettes to depict a simulated Iraqi corps area of operations that did not require a training range, troops or equipment. Similarly, other training and testing could be conducted using simulations without the coordination and use of ranges or soldiers.

JADS Measure 1-2-3-18. Degree to which ADS can provide for improved modeling and simulation (M&S) used for testing.

JADS Measure 1-2-3-23. Degree to which ADS can provide high fidelity emulators and simulators used as targets and/or threats.

ADS technology can provide vastly improved models and simulations for use in testing. Because of the distributed nature of ADS, the tester no longer has to have all test assets physically located in a single location. This saves the expense of purchasing the models and simulations and the difficulty involved in manning the simulated systems. Using the ETE Test as an example, if the Army desired to test any Army components used in the test, they could obtain radar reports from VSTARS without owning and manning (with Air Force personnel) their own VSTARS. ADS technology literally makes models and simulations a phone call away.

ADS also allows the tester to assemble, using models, simulations, emulators, and fielded systems, systems of systems that either have not yet been built or would not exist except in time of war. Again using the ETE Test as an example, the first time that an ATACMS missile was fired at an enemy force, based on operationally realistic intelligence collected by Joint STARS and processed by an element of ASAS, was during the ETE Test. Yet this is a fielded system of systems. Added to this is the battle damage assessment provided by Joint STARS observing the hulks left behind and the fleeing survivors and the fact that all components were electronically linked and functioning as they would in combat. Using this ADS environment, it is a simple task to add the next generation ATACMS or ASAS and find out how it will function as a component system in this system of systems.

C4ISR system testing can involve many complex and expensive assets that must be brought together for testing. Frequently, the first time that all the systems are together may be during OT, which means that problems may not be found and corrected until that stage of testing. Using ADS, a tester can bring together the actual assets or model/simulation assets before OT, and thus fully exercise a system and identify deficiencies.

By providing inputs via model/simulation assets, ADS enables the tester to satisfy a test requirement limited by cost or safety concerns.

ADS technology is flexible enough to support a wide range of simulation fidelity requirements depending on the type of testing being accomplished. (For example, if a system under test is conducting early developmental testing, the fidelity requirements may be significantly lower than a system approaching OT.)

Lastly, ADS can easily provide models and simulations that represent the threats of today and the threats of tomorrow. All models and simulations of threats, no matter what their fidelity, are data driven. The fidelity is determined by the accuracy and detail contained within the data and the fidelity of the algorithms that use the data to depict the threat. During the ETE Test, the threats used were those currently fielded within the Iraqi Army. They could just as easily have been low observable threats from a future battlefield. Just change the data (radar cross section) and the radar reports change drastically to reflect a potential future battlefield.

JADS Measure 1-2-3-19. Degree to which ADS can improve upon constrained concept of operations.

The concept of operations in a conventional test can be limited by such factors as size, threat, topography, and environmental considerations. Thus, certain MOEs and MOPS may not be evaluated because of hazards to soldiers and equipment, insufficient numbers of soldiers and equipment, or weather and terrain considerations. Using simulations in an ADS environment can overcome many of these difficulties. Simulations can be created to depict how the SUT may perform in a robust environment with sufficient assets and under unsafe conditions without the restrictions of weather and terrain. For example, one scenario created for A-tracker testing consisted of hundreds of vehicles in a tight line abreast formation traveling at greater than normal military speeds and conducting difficult maneuvers over a very large area. For various reasons, the specifications that drove this scenario would never be able to be tested in a live test. Distributed testing also allows for the use of nodes at different sites to test the same SUT. Soldiers and equipment don't have to be deployed to a common area, which reduces the coordination, logistics, and cost of testing and training. The concept of operations can be easily expanded to fully assess the system under test.

JADS Measure 1-2-3-24. Degree to which ADS can enable the use of correct techniques and procedures.

Prior to the use of ADS in the ETE Test, intelligence data from Joint STARS, if any, were usually supplied to the ASAS in the form of verbal or written reports. This was because without ADS there was no way to link Joint STARS to the test scenario and provide operationally significant radar reports. This was an incorrect technique and/or procedure. The ground-based portion of Joint STARS, the LGSM, was supposed to be electronically linked to the ASAS workstation and radar reports passed to the analysts working within the analysis and control element (ACE). The use of ADS in the ETE Test enabled the use of correct techniques and procedures.

JADS Measure 1-2-3-25. Degree to which ADS can ensure realistic test scenarios.

Conventional T&E typically suffers from inadequate test scenarios because of the limited number of entities and the available exercise area. In contrast, neither the number of entities nor their movement limit simulations used in an ADS environment. For example, the Phase 4 scenarios depicted the key elements of several Iraqi corps conducting offensive and defensive operations. They included almost 10,000 entities and the entire array of personnel and equipment assigned to a corps-size element. The layout and maneuver of the Iraqi corps were created using doctrinal templates and portrayed tactical movements. According to the LGSM soldiers, the scenarios in the ETE test were the most realistic that they had ever used for training or testing.

As in the ETE Test, realistic scenarios can be created using simulations for many different types of tests. The technology required to make them realistic, and the software and hardware to distribute them to different sites already exist.

JADS Measure 1-2-3-26. Degree to which ADS can facilitate model/simulation data collection.

Although ADS does not impact the internal data collection of a model/simulation node, it can impact the accessibility of critical data. ADS technology can enable the transfer of large amounts of data from one node to another in a timely and secure manner using the same transmission lines employed in the test architecture. This capability for distributed access to data can reduce the need to manipulate or analyze data at each individual network node. In addition, ADS tools allow for the monitoring of data going to and from a site during a test event, either in real or near real time. Thus, the tester can observe and analyze key data elements during a test, making changes to the test if necessary. In contrast, the typical conventional test must be completed before all data can be accessed and problems identified.

JADS Measure 1-2-3-29. Degree to which ADS can increase test resources (supplies).

The test resources (supplies) involved in the setup and execution of the Phase 4 test were examined to determine which resources would not have been required for a traditional test. In addition, the amount of resources (supplies) required for the test, due solely to ADS-specific requirements, was documented.

ADS tests, unlike traditional tests, require resources (supplies) related to the network and distributed nodes. A great deal of additional network and communication equipment is needed to ensure network reliability and good communication at all nodes. In addition, an increased amount of computer equipment is required at the distributed nodes to run the simulations involved in ADS tests. Any support materials required at the distributed nodes would also account for an increase in test resources (supplies) for ADS tests.

JADS Measure 1-2-3-30. Degree to which ADS can represent indirect fire tactics and capabilities.

ADS can realistically portray indirect fire tactics and capabilities. The ETE Test Phase 4 configuration used the AFATDS command and control system, collocated with the TAC at Fort Hood, to request fire missions. TAFSM, located at Fort Sill, processed the fire missions and executed them. When the ATACMS missile was fired in TAFSM, a fire PDU was broadcast from TAFSM. The Janus operator, located at TRAC-WSMR, was alerted that a mission was underway so that, if desired, the operator could zoom in on the strike area and observe the effects. At the appropriate time, a detonate PDU was issued by TAFSM giving the calculated spill location for the missile's bomblets. Janus than calculated the spill pattern for the bomblets and assessed the appropriate damage to the targets located within the spill's footprint. Once the damage was assessed, Janus than broadcast ESPDUs reflecting the effects of the missile strike. This was a doctrinally correct representation of an ATACMS missile strike using approved missile flyout algorithms and approved weapons effects algorithms.

JADS Measure 1-2-3-31. Degree to which ADS can represent joint/combined operations and capabilities.

ADS can realistically portray joint/combined operations. The Phase 4 ETE OT was a joint operation that employed a mix of Air Force and Army personnel located at different facilities successfully simulating a C4ISR system interacting with ground-based units. Given the necessary planning and resources, ADS could also represent combined operations between forces of two or more allies. The simulation used, Janus, is capable of portraying up to six different categories of forces. Since the scenario was set in Iraq, it would have been a simple matter to include forces from Kuwait in the scenario thereby creating a combined operation.

JADS Measure 1-2-3-34. Degree to which ADS can provide for real-time analysis.

This measure examines the ability of ADS test participants to conduct real-time analysis during testing. For the Phase 4 test, network monitoring tools and the Janus/logger data collection capabilities provided data to JADS analysts allowing for limited real-time analysis. These tools provided data on the network links, PDU rates, types of PDUs being passed, and the total number of PDUs logged at each node. Analysis of these data during Phase 4 trials was important in ensuring that the test was functioning properly with all nodes passing the expected amount and type of data.

This real-time analysis was limited by the analysts' inability to manipulate the log files during testing, using tools in the JADS Analysis Toolbox. The log files could not be manipulated during testing without losing test data. In addition, the initial analysis of these log files had to be delayed until immediately after each Phase 4 trial.

JADS Measure 1-2-3-36. Degree to which ADS can increase personnel resources.

The duties of all personnel involved in the setup and execution of the Phase 4 test were examined to determine which personnel would not have been required for a traditional test. In addition, the number of personnel participating in the test, due solely to ADS-specific requirements, was documented.

The ETE Test Phase 4 results did not provide any set formula for forecasting personnel needs. Rather, the exact personnel requirements for C4ISR system testing in an ADS-enhanced live test environment appear to vary from test to test. With this caveat in mind and using just the ETE Test team requirements, an ADS environment does not appear to add to the personnel needs of a C4ISR test. Six JADS personnel were continually involved in ETE Test management and planning, a number equivalent to the staff needed to direct the day-to-day operations of a conventional C4ISR test of the same magnitude. Thirteen people were involved in test monitoring and data collection at the various ETE Test nodes during the actual execution of the Phase 4 FI, risk reduction, and operational tests. Given the distributed nature of C4ISR systems, a similar number of people would be needed in a comparable, traditional C4ISR test. Two N&E personnel were needed for network support during the execution of Phase 4, and two analysts handled the subsequent data analysis and reduction. However, a conventional C4ISR SUT would probably need at least two, and maybe more, network engineers because of its distributed nature, since it might not be as reliable as the ETE Test Phase 4 network. In addition, the C4ISR environment would likewise require a minimum of two data analysts.

4.2 JADS Issue 2. What are the critical constraints, concerns, and methodologies when using ADS for T&E?

The Phase 4 ETE Test demonstrated that there were no real technical barriers to using an ADS-enhanced live test environment to provide a realistic test environment for a C4ISR system. This is due to the high reliability of the network architecture underlying an ADS environment and the dramatic increases in computer processing and storage capabilities over the past few years. Rather, the key constraints to ADS-enhanced testing are time and money. How soon do you need results? How much are you willing to spend on development?

The following paragraphs discuss constraints and concerns in detail.

4.2.1 JADS Objective 2-1. Assess the critical constraints and concerns in ADS performance for T&E.

4.2.1.1 JADS Subobjective 2-1-2. Assess network and communications performance constraints and concerns.

JADS Measures 2-1-2-2. Number of ADS trials canceled or otherwise not used because of network problems.

JADS Measures 2-1-3-3. Number of trials in which network connections were lost long enough to require trial cancellation.

For these measures, the network was defined as including all software and hardware used for connecting the distributed sites and all loggers and instrumentation used for recording network data. NIUs were considered part of the individual simulations and not part of the network.

For each trial, an execution log was maintained at each node. The data collectors annotated all problems encountered as well as their causes. A test controller log also documented the overall status of the network and test trials. In addition, network monitoring tools were used to monitor the status of all network links between nodes. Any problems detected by the monitoring tools were documented via line printers in terms of a brief explanation of the problem, the time, and the link(s) involved.

The risk reduction efforts taken during the previous ETE Test phases helped to ensure the reliability of the network during Phase 4. Table 4 shows the dates of the Phase 4 trials and their test times.

Table 4. ETE Test Phase 4

Trial	Vignette	Test Time	Comments
15 Mar 99	3	N/A	Trial canceled
16 Mar 99	2	6 hrs, 58 mins	
17 Mar 99	3	7 hrs, 44 mins	
19 Mar 99	3	5 hrs, 49 mins	Live flight
24 Mar 99	3	7 hrs	
25 Mar 99	3	5 hrs, 52 mins	Live flight
29 Mar 99	4	7 hrs, 3 mins	
30 Mar 99	5	5 hrs, 55 mins	
31 Mar 99	5	3 hrs, 48 mins	Live flight

JADS Measure 2-1-2-3. Average and peak bandwidth used by link.

This measure provided an indication of bandwidth use and packet rate during the OT. Although bandwidth utilization was not expected to exceed capacity, the utilization rate was documented to provide other ADS testers with an indication of the amount of needed bandwidth. The packet rate data are also included because of their potential value to other ADS testers.

Data were collected using the SPECTRUM® network analysis tool. SPECTRUM® provided the capability to study multiple aspects of network link performance including packet rate and percentage of bandwidth utilized. A polling rate of fifteen seconds was used in the collection of these data.

Once all the data were gathered, the JADS analysts consolidated the data by network link. These data were then used to calculate daily packet rate and bandwidth values (maximum and average) for each link. SPECTRUM® provided the bandwidth values as the percentage of bandwidth available on the T-1 line. A T-1 line has a normal bandwidth of 1.544 megabits per second (Mbps). For the ETE Test, some of the bandwidth of the T-1 line was reserved for voice traffic leaving a maximum bandwidth available of 1.344 Mbps.

Table 5 shows average and maximum performance values for the classified network links monitored during the eight days of active ETE Phase 4 testing.

Packet rate and bandwidth utilized across the three network links varied across the eight days of testing depending on the scenario being run and the availability of each link. Data traffic patterns also differed between live flight (19, 25, and 31 March) and nonlive flight test days. The packet rate experienced over the TCAC-Northrop Grumman link ranged from 10.6 to 19.8 packets per second, on average utilizing less than 1% of the link's bandwidth capacity. Average utilization of the remaining network links was similarly low, as expected, since the Northrop Grumman-Fort Hood link was not utilized to pass data traffic on live flight days, and the Fort Hood-TCAC link was only used as an alternate traffic route when one of the other links experienced equipment problems or outages. Average packet rate over the Northrop Grumman-Fort Hood link ranged from 15.6 to 28.3 packets per second on nonlive flight test days. Nontest related residual data over the Fort Hood-TCAC link resulted in a 4 packet per second data rate. The maximum packet rate for any network link during the eight test days was 345 packets per second, experienced over the TCAC-Northrop Grumman link on 29 March 1999, resulting in a peak load of 69% of bandwidth capacity. The maximum packet rate over the Northrop Grumman-Fort Hood link was 93 packets per second, experienced on 17 March, a nonlive flight day, with a corresponding load of 4%. All atypical traffic flow on the Fort Hood-TCAC link, the greatest of which resulted in a peak 31 per second packet rate, was caused by equipment outages on other network links, since data were automatically rerouted across the remaining usable links. Occasional equipment problems involving any one network link usually lasted no longer than three minutes and were transparent to the user, proving the utility of network link redundancy. No test time was lost because of network equipment.

Table 5. Link Performance Characteristics*

Day	Node A	Node B	Load Average	Load Maximum	Packet Rate Average	Packet Rate Maximum
16 Mar 99	T	G	0.5 %	9 %	15.9/sec	60/sec
	G	H	0.5 %	4 %	25.4/sec	92/sec
	H	T	0 %	0 %	2.9/sec	4/sec
17 Mar 99	T	G	1.2 %	12 %	19.6/sec	69/sec
	G	H	0.6 %	4 %	25.2/sec	93/sec
	H	T	0 %	0 %	2.9/sec	3/sec
19 Mar 99	T	G	0.9 %	5 %	19.8/sec	55/sec
	G	H	0 %	2 %	1.1/sec	29/sec
	H	T	0 %	6 %	3.1/sec	31/sec
24 Mar 99	T	G	0.3 %	2 %	11.3/sec	89/sec
	G	H	0 %	1 %	15.6/sec	28/sec
	H	T	0 %	3 %	4.1/sec	19/sec
25 Mar 99	T	G	0.9 %	67 %	17.1/sec	310/sec
	G	H	0 %	0 %	1.1/sec	15/sec
	H	T	0 %	3 %	4.1/sec	18/sec
29 Mar 99	T	G	0.7 %	69 %	14.4/sec	345/sec
	G	H	0.6 %	4 %	28.3/sec	93/sec
	H	T	0.1 %	2 %	4.2/sec	19/sec
30 Mar 99	T	G	0.3 %	1 %	10.6/sec	21/sec
	G	H	0.4 %	4 %	26.5/sec	92/sec
	H	T	0 %	3 %	4/sec	15/sec
31 Mar 99	T	G	0.3 %	2 %	12/sec	86/sec
	G	H	0 %	0 %	1/sec	2/sec
	H	T	0 %	0 %	3.9/sec	4/sec
Total	**T**	**G**	**0.6 %**	**69 %**	**15.1/sec**	**345/sec**
	G	**H**	**0.3 %**	**4 %**	**15.5/sec**	**93/sec**
	H	**T**	**0 %**	**6 %**	**3.7/sec**	**31/sec**

T = TCAC G = Northrop Grumman H = Fort Hood

* Table refers only to active test time during which PDU loggers were recording data.

JADS Measure 2-1-2-5. Percentage of time PDUs were received out of order by a network node.

JADS Measure 2-1-2-6. Percentage of total PDUs required at a node that were delivered to that node.

JADS Measure 2-1-2-7. Average and peak data latency between ADS nodes.

The flow of PDUs to and from each node was recorded using loggers installed as part of the network architecture. The loggers specifically recorded the time and order that the PDUs were transmitted and received at each node.

The raw logger data were transformed and reduced for analysis to determine out of order PDUs, duplicate PDUs, lost PDUs, and PDU latency. These data were then used to calculate the percentage of out of order, duplicate, and lost PDUs at each node for each vignette and for the test as a whole. The minimum, maximum, and mean latency of PDUs were also computed. JADS analysts accomplished these calculations using UNIX®-based software tools created by JADS programmers.

Tables 6 and 7 describe the results for these measures. Table 6 shows the PDU data for each vignette by node; there were no duplicate or out of order PDUs. Table 7 provides the latency data for the vignettes broken down into the individual network links between nodes. These tables indicate the high reliability of the network in passing PDUs and the network ability to maintain stable latencies during the Phase 4 test.

Table 6. Vignette PDU Data

Day	Node A	Node B	PDUs Sent	PDUs Received	PDUs Lost/ Percent Lost
16 Mar 99	W	T	91,117	91,088	29 0.03%
	T	G	91,088	90,096	992 1.09%
	S	W	4,695	4,684	11 0.23%
17 Mar 99	W	T	167,396	165,824	1,572 0.94%
	T	G	165,824	165,711	113 0.07%
	S	W	4,679	4,679	0 0%
19 Mar 99 (Flight)	W	T	122,211	120,724	1,487 1.25%
	T	G	120,724	120,618	106 0.09%
	S	W	2,998	2,998	0 0%
	NIU	E-8C	120,618	120,190	428 0.35%

Table 6. Vignette PDU Data (cont.)

Day	Node A	Node B	PDUs Sent	PDUs Received	PDUs Lost/ Percent Lost
24 Mar 99	W	T	142,332	140,977	1,355 0.95%
	T	G	140,977	139,939	1,038 0.74%
	S	W	3,709	3,709	0 0%
25 Mar 99 (Flight)	W	T	131,559	130,581	978 0.74%
	T	G	130,581	130,025*	556* 0.43%
	S	W	3,473	3,473	0 0%
	NIU	E-8C	130,025	129,798	227 0.17%
29 Mar 99	W	T	100,477	100,367	110 0.11%
	T	G	100,367	99,893*	474* 0.47%
	S	W	4,673	4,672	1 0.02%
30 Mar 99	W	T	111,391	111,094	297 0.27%
	T	G	111,094	110,933	161 0.14%
	S	W	3,958	3,958	0 0%
31 Mar 99 (Flight)	W	T	86,973	86,787	186 0.21%
	T	G	86,787	86,787	0 0%
	S	W	1,904	1,904	0 0%
	NIU	E-8C	86,787	77,595	9,192 10.59%
Total	W	T	953,456	947,442	6,014 0.63%
	T	G	947,442	944,002	3,440 0.36%
	S	W	30,089	30,077	12 0.04%
	NIU	E-8C	359,144	349,297	9,847 2.74%

W= WSMR T = TCAC G = Northrop Grumman S = Fort Sill

* For the 25 and 29 March tests, the numbers indicated for PDUs received were taken from the loggers. However, analysis of the Northrop Grumman log files for 25 and 29 March showed much lower PDU numbers at the Northrop Grumman node (108,020 and 91,119, respectively). These PDU losses resulted from computer work done at the Northrop Grumman node during test days. The work was stopped following the 29 March test, and the problem was resolved.

Table 7. Vignette Latency Data

Day	Node A	Node B	Latency (seconds)		
			Minimum	Maximum	Mean
16 Mar 99	W	T	0.017	0.131	0.039
	T	G	0.048	0.280	0.053
	S	W	0.039	0.348	0.038
17 Mar 99	W	T	0.019	0.172	0.052
	T	G	0.048	0.279	0.059
	S	W	0.036	0.373	0.038
19 Mar 99 (Flight)	W	T	0.020	0.162	0.052
	T	G	0.042	0.169	0.061
	S	W	0.037	0.370	0.038
	NIU	E-8C	1.58	41.68	12.08
24 Mar 99	W	T	0.020	0.173	0.050
	T	G	0.039	0.186	0.060
	S	W	0.035	0.379	0.037
25 Mar 99 (Flight)	W	T	0.018	0.178	0.047
	T	G	0.047	0.291	0.059
	S	W	0.035	0.376	0.038
	NIU	E-8C	2.82	29.95	12.99
29 Mar 99	W	T	0.019	0.156	0.046
	T	G	0.048	0.289	0.058
	S	W	0.037	0.395	0.038
30 Mar 99	W	T	0.020	0.161	0.044
	T	G	0.041	0.224	0.056
	S	W	0.035	0.385	0.038
31 Mar 99 (Flight)	W	T	0.018	0.157	0.041
	T	G	0.045	0.177	0.055
	S	W	0.036	0.399	0.035
	NIU	E-8C	2.06	85.57	12.60
Total	W	T	0.017	0.178	0.046
	T	G	0.039	0.291	0.058
	S	W	0.035	0.399	0.038
	NIU	E-8C	1.58	85.57	12.56

W= WSMR T = TCAC G = Northrop Grumman S = Fort Sill

Tables 6 and 7 show the reliability of the network in passing PDUs and maintaining low latencies during the Phase 4 risk reduction and OT. The PDU data in Table 6 show total PDU loss rates of 0.63, 0.36, and 0.04 percent for the WSMR-TCAC, TCAC-Northrop Grumman, and Fort Sill-WSMR links respectively. These percentages equate to an overall PDU loss rate of 0.49%. This PDU loss rate is much lower than the loss rate experienced during the Phase 3 test (1.63%) and is well below the criterion of 5% set for overall PDU losses. This suggests a high level of reliability was experienced during the test events.

The latency data in Table 7 show that the average latency for the TCAC-Northrop Grumman and Fort Sill - WSMR links was very stable over the eight days of testing, varying by less than 10%. However, the WSMR-TCAC link exhibited relatively large variations in latency (up to 33%). The latency over the TCAC-Northrop Grumman link had maximum values of almost 400 milliseconds. However, these were only transient values and did not significantly affect the average latency of the links. The average total latency for the ESPDU data to travel from the WSMR node to the Northrop Grumman node was just over 100 milliseconds and had no effect on the validity of the Phase 4 results.

Tables 6 and 7 also show the performance of the SATCOM link during the three live flights. The PDU data in Table 6 show PDU loss rates of 0.35%, 0.17%, and 10.59% during the 19, 25 and 31 March live flights respectively. These rates equate to an overall PDU loss rate of 2.74% for the SATCOM link. The PDU loss rates for the 19 and 25 March live flights are comparable to those of the network links, suggesting that the SATCOM link was highly reliable during these test dates. However, the high PDU loss rate experienced on 31 March suggests that there may have been problems in passing data via the SATCOM link for this trial.

During Phase 4 flight tests on 19, 25 and 31 March, observers noted and analysis confirmed that small groups of entities (1-15) were traveling in straight lines across the GRCA without regard to terrain features such as rivers, lakes or roads. Some of the entities would continue to move until the conclusion of the vignette while others would disappear.

The impact of the wandering entities was noted during the targeting phase at Fort Hood. When the TAC personnel conferred with the Janus operator prior to fire missions, it was noted the wandering entities were not in that location within the Janus simulation. The entities were seen 5 to 25 km from their expected locations. When fire missions were directed at those targets as displayed in the GSM no hits were seen in Janus. As a result of these observations further analysis was conducted. Analysts replayed the data tapes recorded in the GSM and compared them with test logs from all nodes during the three live flights. The GSM tapes were studied for apparent entities that "wandered." The Zulu times of these anomalies were compared to events that were occurring at other nodes.

The analysis revealed three apparent causes for these wandering entities. The first and most notable event resulted from software crashes of the GNIU. When the GNIU is inoperable and not passing VSTARS data packets (VDPs), the entities on board the E-8C will continue to dead reckon on their last received velocity. If an entity changes velocity during the GNIU outage, it will not be passed to the E-8C. There were some cases noted where entities stopped in the Janus vignette during a GNIU outage, and as a result, those entities on the E-8C were continued on their last course and speed for the remainder of the vignette. It was further observed that other entities which changed state during GNIU outages continued on the last course and speed until they received the next change of state from the Janus vignette. These entities that appeared to miss turns during the outages "snapped" back when the next ESPDU from the vignette was received. Although the GNIU outages were not frequent or lengthy, they resulted in the most notable wandering if they occurred during heavy activity (change of state) within the Janus vignettes.

The second cause was loss of VDPs being transmitted to the aircraft from the GNIU. Losses varied in how many and how often they occurred. The losses varied from one lost VDP to 850 lost during a single occurrence. The vast majority of the cases were only several lost VDPs at a time. Table 6 lists the total loss of VDPs for each of the flight days. Monitoring tools were not in place to determine the exact cause of the losses, but they could have resulted from transmission losses from the GNIU to the satellite to reception losses on the aircraft during turns. The majority of these losses would only result in isolated entities wandering off across the GRCA.

The third cause was from PDU losses over the WAN. Table 6 lists the number of PDUs lost during each test event. These losses produced the same symptoms as seen from GNIU crashes or SATCOM losses. The WAN losses were minimal and resulted in the wandering and snapping seen from other causes.

The overall impact on the Phase 4 test objectives from these losses was minimal. Several methods could be used to reduce or eliminate these type of problems in future tests with a similar design. The Phase 4 ETE test design was frozen after the start of the phase and refinements were not allowed to the hardware or software to improve the reliability or performance of individual systems. The impact of GNIU crashes, which were infrequent, as well as the WAN and SATCOM losses, could be reduced by running a simulation with less moving entities or using a heartbeat to update all entities on a regular basis. The heartbeat would "catch" entities that missed a change of state during an outage. The heartbeat during the Phase 4 test was turned off at Janus to minimize the VDP load on the SATCOM link. The SATCOM bandwidth used for this test was 19.2 kilobits per second (Kbits), and it was the limiting factor in the transmission of data. The use of a more robust communication link would allow for the use of a heartbeat even with a large number of movers.

Table 7 shows the latencies experienced on the SATCOM link during the live flights. These latency numbers are much higher than those experienced on the network links: latencies as high as 85 seconds were experienced on 31 March.

Further investigation revealed that these times were, in fact, not latencies, but rather delays in logging the arrival of the data on board the aircraft. The aircraft used its general purpose computers (GPC) to log all local area network (LAN) traffic that occurred. These same GPC also ran the primary radar software and were very busy. Logging on these computers is a secondary task and is often delayed for long periods of time (minutes). During the test, no computers were available on the LAN to dedicate to logging, and JADS was not allowed to add a dedicated logger on board the aircraft.

The smallest delay in logging observed for the satellite link was on the order of 2 seconds. If one assumes that these instances occurred during periods of minimal load on the GPCs, than the latency from the GNIU to the ANIU is no more than 2 seconds and would have little effect on the operators. This assumption was supported both by observation during the flights and by calculations showing that the total transmission and processing times were less than 2 seconds.

Future tests using the actual SUT must come to grips with data logging using nondedicated computers. The Joint STARS JTF, who regularly tests Joint STARS, could accept the delays in logging because its data are not time sensitive. JADS could not but was prevented from modifying the SUT. Testers must identify early in a program's life cycle not only the data that will be collected during testing but also data that are time sensitive as to when they are collected.

JADS Measure 2-1-3-6. Average downtime due to ADS network failures.

This measure identified the impact of network failures on the OT. The network system included the local area networks at the TCAC and Northrop Grumman, as well as the wide area network connecting WSMR to the TCAC, the TCAC to Northrop Grumman, Fort Sill to the TCAC, and Fort Hood to the TCAC. During Phase 4, logs were kept to record all network problems, the start time and duration of the problems, and problem resolution. In addition, network monitoring tools were used to monitor the status of all network links between the nodes. Any problem detected by the monitoring tools was documented via line printers in terms of a brief explanation of the problem, the time, and the link(s) involved.

All the trials executed during the Phase 4 test were successful with PDU losses not exceeding five percent for any trial. For the eight trials that were accomplished, 16 network outages were experienced resulting in a total of 39 minutes of network downtime. Table 8 shows the data on network downtime; Table 9 provides data on the impact of network downtime on PDU losses.

Table 8. Network Downtime

Day	Duration of Trial	Time Network Unavailable for Testing	% of Time Network Unavailable	Reason Unavailable
16 Mar 99	6 hrs, 58 mins	2 mins	0.48%	Router down at Northrop Grumman
17 Mar 99	7 hrs, 44 mins	None	None	Not applicable
19 Mar 99	5 hrs, 49 mins	2 mins	0.57%	Trunk card down at TCAC
24 Mar 99	7 hrs	7 mins	1.67%	Router down at Northrop Grumman; Northrop Grumman port deactivated twice
25 Mar 99	5 hrs, 52 mins	14 mins	3.98%	Trunk card down three times at TCAC; Northrop Grumman port deactivated; router down twice at Northrop Grumman
29 Mar 99	7 hrs, 3 mins	12 mins	2.84%	Trunk card down three times at TCAC; router down at Northrop Grumman
30 Mar 99	5 hrs, 55 mins	2 mins	0.56%	Trunk card down at TCAC
31 Mar 99	3 hrs, 48 mins	None	None	Not applicable
Total	**50 hrs, 9 mins**	**39 mins**	**1.30%**	

Table 9. Analysis of Network Impact on PDUs

Day	Node A	Node B	PDUs sent / PDUs lost	Network-related PDU losses / % of PDUs sent / % of PDUs lost	Unexplained PDU losses / % of PDUs sent / % of PDUs lost
16 Mar 99	W	T	91,117 / 29	0 / 0% / 0%	29 / 0.03% / 100%
	T	G	91,088 / 992	952 / 1.05% / 95.97%	40 / 0.04% / 4.03%
	S	W	4,695 / 11	0 / 0% / 0%	11 / 0.23% / 100%
17 Mar 99	W	T	167,396 / 1,572	0 / 0% / 0%	1,572 / 0.94% / 100%
	T	G	165,824 / 113	0 / 0% / 0%	113 / 0.06% / 100%
	S	W	4,679 / 0	0 / 0% / 0%	0 / 0% / 0%
19 Mar 99	W	T	122,211 / 1,487	0 / 0% / 0%	1,487 / 1.22% / 100%
	T	G	120,724 / 106	75 / 0.06% / 70.75%	31 / 0.03% / 29.95%
	S	W	2,998 / 0	0 / 0% / 0%	0 / 0% / 0%
24 Mar 99	W	T	142,332 / 1,355	0 / 0% / 0%	1,355 / 0.95% / 100%
	T	G	140,977 / 1,038	604 / 0.43% / 58.19%	434 / 0.31% / 41.81%
	S	W	3,709 / 0	0 / 0% / 0%	0 / 0% / 0%
25 Mar 99	W	T	131,559 / 978	0 / 0% / 0%	978 / 0.74% / 100%
	T	G	130,581 / 556	510 / 0.39% / 91.73%	46 / 0.04% / 8.27%
	S	W	3,473	0	0

			0	0% / 0%	0% / 0%

Table 9. Analysis of Network Impact on PDUs (cont.)

Day	Node A	Node B	PDUs sent / PDUs lost	Network-related PDU losses (% of PDUs sent / % of PDUs lost)	Unexplained PDU losses (% of PDUs sent / % of PDUs lost)
29 Mar 99	W	T	100,477 / 110	0 / 0% / 0%	110 / 0.11% / 100%
	T	G	100,367 / 474	432 / 0.43% / 91.14%	42 / 0.04% / 8.86%
	S	W	4,673 / 1	0 / 0% / 0%	1 / 0.02% / 100%
30 Mar 99	W	T	111,391 / 297	0 / 0% / 0%	297 / 0.27% / 100%
	T	G	111,094 / 161	157 / 0.14% / 97.52%	4 / 0.004% / 2.48%
	S	W	3,958 / 0	0 / 0% / 0%	0 / 0% / 0%
31 Mar 99	W	T	86,973 / 186	0 / 0% / 0%	186 / 0.21% / 100%
	T	G	86,787 / 0	0 / 0% / 0%	0 / 0% / 0%
	S	W	1,904 / 0	0 / 0% / 0%	0 / 0% / 0%
Total	W	T	953,456 / 6,014	0 / 0% / 0%	6,014 / 0.63 % / 100%
	T	G	947,442 / 3,440	2,730 / 0.29% / 79.36%	710 / 0.07% / 20.64%
	S	W	30,089 / 12	0 / 0% / 0%	12 / 0.04% / 100%

W = WSMR T = TCAC G = Northrop Grumman S = Fort Sill

Tables 8 and 9 show that the network was reliable during the execution of the Phase 4 test. During the eight trials, the network was down for only 39 minutes or 1.30% of the test period, resulting in relatively few lost PDUs. All the network problems were minor with the majority caused by TCAC trunk card outages or the Northrop Grumman router. In all, 16 periods of network downtime were experienced with each outage lasting between 1 and 3 minutes. These results are comparable to the Phase 3 test, which experienced 1.29% network downtime. The Phase 4 test results also compare favorably to the Phase 3 results in terms of the impact of the network on PDU losses. While the Phase 3 test experienced network-related PDU loss rates of 2.13%, 0.40%, and 1.58% for the three test links, no Phase 4 PDU loss rate exceeded 0.30% due to the impact of network downtimes.

There are two possible explanations for a "lost" PDU. One is that the network lost the PDU either through an outage or because the router dropped the PDU. The other explanation could be that the logger failed to log the PDU. One path of the WAN had four loggers and used four routers. As one proceeded down the path from router to router, each successive logger logged a lower number of PDUs. A downstream logger never logged more PDUs than the preceding logger. This would indicate that the PDUs were lost by the routers.

4.2.1.2 JADS Subobjective 2-1-3. Assess the impact of ADS reliability, availability, and maintainability on T&E.

JADS Measures 2-1-3-1. Percentage of trials delayed, rescheduled, and/or redone because of ADS systems (exclusive of network) unavailability.

JADS Measures 2-1-3-5. Mean operating time between ADS system failures (severe enough to require trial cancellation).

These measures determined the availability of ADS nodes, including the NIUs, and the impact of node failures on Phase 4 testing.

For each trial, an execution log was maintained at each node. The data collectors annotated all problems encountered with the ADS systems along with their causes. A test controller log was also maintained to document the overall status of the trials.

Exclusive of network unavailability, one trial had to be canceled and reaccomplished during the Phase 4 test. This cancellation resulted from a major ADS system failure, which could not be resolved during the scheduled time for the trial. Table 10 lists this trial cancellation along with the other ADS system failures experienced during Phase 4. The table also includes the time required to resolve these failures as well as their impact.

Table 10. ADS System Failures

Day	Failure	Resolution	Duration	Test Time	Impact on Test
15 Mar 99	SCDL down; vignette on tape at Fort Hood	N/A	N/A	N/A	Trial canceled
16 Mar 99	No ADS system failures	N/A	N/A	6 hrs, 58 mins	N/A
17 Mar 99	Entities straying from roads on VSTARS	VSTARS brought down for adjustments	25 mins	7 hrs, 44 mins	Trial paused while VSTARS was down
	VSTARS crashed due to disk usage problem	Disk usage examined; VSTARS rebooted	1 hr, 42 mins		Trial paused while VSTARS was down
19 Mar 99	No ADS system failures	N/A	N/A	5 hrs, 49 mins	N/A
24 Mar 99	VSTARS crash due to SAR SIM	VSTARS rebooted	17 mins	7 hrs	Trial paused while VSTARS was down
	VSTARS crash due to continuing SAR SIM problems	VSTARS rebooted	45 mins		Trial paused while VSTARS was down
	Time problem (Fort Hood to Fort Sill) due to ASAS machine	Time updated on ASAS machine at Fort Hood	15 mins		No fire missions executed until time problem resolved
25 Mar 99	AFATDS at Fort Hood crashed	AFATDS rebooted	15 mins	5 hrs, 52 mins	Some fire missions lost; fire missions stopped until problem resolved
	MTI SIM crashed on E-8C	Problem not resolved while on station	1 hr, 2 mins		One hour of time-on-station data collection was lost
29 Mar 99	SAR SIM not working at Northrop Grumman	Hardware problem found and resolved	1 hr, 25 mins	7 hrs, 3 mins	Degraded imagery provided to Fort Hood
30 Mar 99	No ADS system failures	N/A	N/A	5 hrs, 55 mins	N/A
31 Mar 99	MTI SIM crashed on E-8C	Problem not resolved while on station	10 mins	3 hrs, 48 mins	Ten minutes of time-on-station data collection were lost

Extensive risk reduction testing was instrumental in preventing any major ADS system failures from affecting the Phase 4 test. A total of ten ADS system failures occurred during the nine days of testing. One trial was canceled because of ADS failures, i.e., the failure to establish SCDL or run a taped vignette from Fort Hood on 15 March. In addition to this cancellation, there were three trials that were delayed for more than an hour because of ADS system failures. One trial during the risk reduction portion of Phase 4 and one trial during the OT were delayed for more than an hour because of VSTARS crashes. An MTI simulation crash on the E-8C accounted for the other lengthy ADS system delay. These three failures, along with the remaining ADS system failures, accounted for a total of 6 hours 46 minutes of test time.

4.2.2 JADS Objective 2-2. Assess the critical constraints and concerns in ADS support systems for T&E.

4.2.2.1 JADS Subobjective 2-2-1. Assess the critical constraints and concerns regarding ADS data management and analysis systems.

JADS Measure 2-2-1-1. Degree to which ADS nodes provide for collection, data entry, and quality checking of pre- and post-trial briefing data.

Quick-look analysis of results was used to support the post-trial briefings. This analysis relied primarily on automated data collection at all ETE Test nodes. The data collection tools included the JADS logger, which collected the PDU log files, and a SPECTRUM® logger to monitor network performance. Data collection tools were attached to the network at each node without any impact on network or node performance. At the end of each test day, the data were remotely retrieved by the TCAC and the file size checked. This procedure supported timely quick-look analysis and test feedback.

In addition to electronic data logs, manually written logs were kept at each test site and used to support post-trial briefings. During the Phase 4 test, a daily after-action teleconference call was conducted. This enabled the test controller to discuss and fully understand the problems of the day without having to review local log sheets.

As mentioned previously, no instrumentation of the SUT was allowed. This caused the previously discussed problem with the post-test measurement of satellite link latencies. However, test observers were unable to observe any latency effects during the conduct of the test. This would indicate that the latency involved had no effect upon the test.

JADS Measure 2-2-1-2. Adequacy of relevant test data storage at ADS nodes.

The ETE Test analysis requirements drove test data storage needs. The focus of data analysis at each site was on network latency as well as on the actual PDU input or data output at each site. The need to record PDU traffic at each node required a determination of the data output and reception rates at all sites. The largest contributor to ESPDU traffic was the output of the Janus simulation. ESPDUs from Janus are a function of the Janus heartbeat and the vignette design.

During the Phase 2 testing, the Janus heartbeat was set to update all entities every fifteen minutes during the first hour. In addition, Janus had to output an ESPDU when an entity changed state, i.e., start, stop, turn, etc. As a result, the ESPDU output grew as the number of movers increased. The ETE Test was planned with the use of five different vignettes ranging from prehostility with a low number of movers to an active battle vignette with more than 3,000 entities moving at one time. Prior to Phase 4 testing, the five vignettes were played and the ESPDU output recorded. The maximum file size seen during this testing was about fifteen megabytes. To support the data recording as well as file storage and local software requirements, the JADS Network and Engineering team installed 4-gigabyte hard drives on the SGI Indy at each node.

During preparations for the Phase 4 test, the Northrop Grumman node required the largest data capacity in order to support VSTARS software testing in a stand-alone mode. This testing required the playback of PDU files recorded from TRAC-WSMR to VSTARS. All five vignettes were played back at various times, and at least five vignette PDU files were stored on the SGI Indy at all times. During actual Phase 4 testing, the ETE Test team found hard drive data storage capacity to be more than adequate.

At one point during the development of the test, a desire to record ground truth data on each entity was expressed. These data would be used to determine the performance of the virtual radar during the flight in the same manner that time-space-position information (TSPI) data are used to determine the actual radar's performance during a flight. It was quickly determined that the Joint STARS JTF would be unable to process and sort out the data on 10,000 entities and the request was cancelled. Recording of these data, however, would have required the addition of additional disk capacity to the aircraft, an action we were prevented from doing.

The development of data storage needs required a full understanding of each node's requirements. Since the cost of hard drive storage has decreased dramatically over the past few years, it was cost effective to allow for unexpected growth by significantly exceeding the expected storage requirements.

JADS Measure 2-2-1-4. Ease with which data can be retrieved post trial from a given node.

During Phase 4 of the ETE Test, automated data were collected using PDU loggers at the nodes, and operational data were collected using log sheets at each node. Automated data on the SATCOM link were collected using logging software developed by Northrop Grumman. The automated data collected at the other JADS test locations during the test were retrieved by the TCAC using file transfer protocol (FTP), while JADS personnel transported the log sheets to JADS. The automated data were compressed and converted for analysis using JADS UNIX®-based tools.

The automated data retrieval process was very effective. For the ETE Test Phase 4, the automated data retrieval process needed about thirty minutes despite the large size of the log files being converted. Also, there were no problems encountered during any retrieval efforts. As exemplified by the ETE Test team's data retrieval process, any ADS data retrieval methodology need not be complex.

4.2.2.2 JADS Subobjective 2-2-2. Assess the critical constraints and concerns regarding configuration management of ADS test assets.

JADS Measure 2-2-2-1. Degree to which test managers can control the configurations of ADS participants, the ADS environment data, and ADS networks.

This measure determined if the test manager could adequately control the test configuration of ADS participants, the ADS environment data, and the ADS network during and between test events. The JADS analysts conducted interviews with the test team members involved in configuration management on the Phase 4 test. The JADS analysts also monitored the progress of test and network configuration from formal integrated product team (IPT) and requirements meetings.

Configuration control for the ETE Test synthetic environment proved to be a challenge. The distributed nature of the test made configuration control more complex because of the many different organizations involved in the test. Unlike a single-site test effort, the ETE Test involved more than half a dozen organizations and two branches of the military. The added difficulty of the distributed network made frequent technical meetings and formal IPTs a must. These meetings provided the test manager with the ability to track progress and problems with the network configuration and data formats. These meetings also provided the forum for the system experts to resolve the issues with all those who were affected.

This process proved to be effective in controlling the Phase 4 configuration during the test build-up and preparation phase. In addition, there were no configuration control problems during the OT execution.

Configuration control of an ADS test can add significant management issues when compared to non-ADS efforts. This added complexity requires a higher level of involvement by the test manager as well as more frequent face-to-face meetings among technical personnel from the various ADS test nodes. An ADS test manager's job would be eased with the aid of an integration engineer.

4.2.3 JADS Objective 2-3. Develop and assess methodologies associated with ADS for T&E.

4.2.3.1 JADS Subobjective 2-3-2. Develop and assess methodologies associated with test execution and control for tests using ADS.

JADS Measure 1-2-2-3. Degree to which test exercise/control features can be improved through experimentation using an ADS environment.

JADS Measure 2-3-2-3. Degree to which protocols, processes, and procedures are needed to enable effective centralized test control.

These measures determined the degree to which test exercise/control features could be improved through experimentation, and the degree to which protocols, processes, and procedures were needed to enable effective centralized test control in a distributed environment. JADS personnel analyzed test logs, test team discussions, and after-action reports to determine the effectiveness of the test control procedures and if the test exercise/control features had been improved.

The test exercise/control procedures used during the Phase 4 test were developed and refined during the previous test phases. These procedures included standardized checklists addressing the start-up and shutdown of the ETE Test network and the conduct of each test trial. The network checklist included procedures to verify network connectivity, data storage space, and time server accuracy, and to test network transmission prior to test start. The test conduct checklist included detailed start-up procedures for each test node. These checklists are provided in Appendix A to this report.

Communication procedures were also developed during the previous test phases. Based on the experience gained during these tests, the Phase 4 testers were able to use the conference phone lines to effectively resolve system failures and to facilitate useful discussions of the after-action reports. The only exception to this occurred during the first live flight on 19 March. Numerous communication problems were experienced during the flight because of failed communication links and inadequate test start-up/communication procedures between the TCAC and the aircraft. These problems were resolved once the aircraft arrived at Fort Hood and established contact with the LGSM. Following the 19 March flight, specific procedures for contacting the aircraft and TCAC were established along with revised procedures for start-up during live flights.

Effective centralized test control was exercised through the test controller located at the TCAC. The test controller was responsible for starting and stopping each trial, monitoring the status of all nodes and network links, and declaring holds and restarts when necessary. The test controller was able to continuously monitor the status of the trials through a combination of network monitors in the TCAC and voice communications with key personnel at each site. These procedures proved effective for timely detection and resolution of system/network failures.

Test exercise/control in a distributed computing environment offers many challenges not experienced in conventional testing. The designers of a test network should carefully plan for test exercise/control, noting that good communication is required among all network nodes. Otherwise, poor test control can result in inaccurate and untimely information being disseminated throughout the test architecture and can waste valuable test time and test assets. Such test exercise/control features should also be examined following testing activities. Lessons learned from experimentation in an ADS environment should be applied to test exercise/control in order to improve how future tests in the ADS environment are conducted.

5.0 Lessons Learned

5.1 Technical Lessons Learned

5.1.1 Simulations

When used in ADS testing, simulations should be carefully planned and developed. The ADS tester must also be in close communication with each organization modifying simulations crucial to the test. The ETE Test Phase 4 succeeded because of the relatively high degree of reliability of the simulations used in the test. If simulation execution problems had occurred, the ETE Test team had arranged for a quick response by the personnel needed to fix those difficulties.

Simulation software must be kept under strict configuration control. If an error is found in the software, software configuration management allows the error to be identified with a particular version of the software and ensures that the needed software fix will be included in all later versions.

5.1.2 Interfaces

Distributed testing often requires linkage among dissimilar facilities, network equipment, and simulations. However, careful planning can significantly reduce the potential for difficulties arising from network interface problems. As part of its planning, the ETE Test team bought standard network equipment for all the sites. Thus, the configuration of the ETE Test environment did not pose any problems during the Phase 4 test.

5.1.3 Networks

Time sources must be synchronized. Time must be synchronized from the same time source, then validated at each network node to ensure that accurate, synchronized time is recorded at each node. The time server used in the ETE Test worked very well, ensuring that all loggers were set at the same time and keeping time differences between loggers to a minimum. Having the same time at all loggers helped speed up the analysis and allowed for the use of automated analysis tools.

The use of the satellite link during Phase 4 resulted in the existence of two networks. The WAN that was time synched based upon a GPS signal, and a LAN internal to the aircraft that was also time synched by a GPS signal. There was no way to compare the two times, so the assumption was made that the two time domains were within the test's established tolerance of one millisecond. This is a reasonable assumption for a test of a man-in-the–loop C4ISR system.

5.1.4 Instrumentation

Special equipment was necessary for ADS network check-out and verification. Special test equipment and networking tools will rapidly isolate the specific cause of network and ADS/DIS problems. Without the special equipment, troubleshooting would have been accomplished by trial and error increasing time, cost, and personnel. In addition, the key Network and Engineering personnel should be trained in the use of the special test equipment and networking tools.

The flow and transfer of PDUs were critical to the ETE Test. PDU traffic was continuously monitored at all nodes to ensure that PDUs were constantly flowing. Since the ETE Test manning levels were insufficient to enable watching these monitors at all time, problems that interrupted PDU flow were not always immediately noticed. Some type of audio warning device might have reduced test time loss from a few minutes to seconds.

5.2 Infrastructure and Process Lessons Learned

5.2.1 Procedures

5.2.1.1 Planning

- The requirements for an ADS test must be clearly defined early in the test planning phase. Detailed planning and coordination are required to ensure a common understanding of all requirements, procedures, and test objectives since individual facilities are generally unfamiliar with conducting coordinated, distributed T&E tests.

- When planning for the integration of a major activity into the ADS environment, provide plenty of time for risk reduction testing. In addition, allow time between major test events to fix problems should they occur. For example, downtime was scheduled following the 25 March live flight to allow resolution of any problems that occurred during the flight and before the next test event. Only minor problems were experienced, and there was sufficient time to resolve these difficulties before the 31 March live flight.

- Be open to new ideas, as some of the old ideas from the early stages of an ADS test program may become very expensive to bring to fruition. The ETE Test Phase 4 was originally slated to have nine scenarios. As the requirements for each scenario increased, development costs also grew. These added costs eventually led to the deletion of the last four scenarios.

- Minimize the impact of hardware problems. When using a complicated ADS network with a vast array of equipment, hardware problems will occur. Plan in such a way that unexpected hardware problems do not completely disrupt the test. During the ETE Test Phase 4, steps were taken to ensure that hardware problems did not disrupt the test for long periods of time. For example, data saves were accomplished frequently. In addition, the network was constantly monitored to ensure that hardware problems were fixed as soon as possible.

5.2.1.2 Development

- Use a stepping stone approach to testing where each successive ADS test builds on the success of earlier tests. This "test, analyze, fix, test" approach, in concert with structured, independent testing of the network, will greatly improve the chances for successful ADS testing.

- Risk reduction testing prior to actual test execution will help test team personnel identify and resolve potential ADS system problems.

5.2.1.3 Execution

- Briefings are needed before each ADS test. These briefings should include such information as the test objectives, telephone numbers to use for test control, the test configuration of each facility, instrumentation and data collection requirements, go/no go criteria, contingency and backup plans, and test conduct. A briefing checklist should be developed and used. These procedures should be established and understood by all ADS test participants. In addition, these procedures should be reviewed for accuracy when requirements or nodes are added to the test.

- Test control procedures should be well rehearsed. When many people are communicating on one phone line, a response order should be established and strictly followed to save valuable test time.

- Communication and coordination among ADS test team members are vital for the success of an ADS test especially when changes or additions are made to the test environment.

- Do not allow test personnel to use test equipment for purposes other than the test being conducted. Use of one of the loggers to compile test analysis code during the conduct of a trial caused PDUs to not be recorded and resulted in an incomplete log file.

5.2.1.4 Evaluation

- Effective data management is needed. Linked facilities can generate a large volume of data at distributed locations. Without careful planning, key data may not be collected and/or transmitted to the analysis center, and data collected at the network nodes may not be in a useful form for centralized analysis. Before ADS testing, a comprehensive data management plan must clearly identify the data to be collected at each network node, on-site processing of the data, and the data to be transmitted to the analysis center.

- Pretest rehearsals are also useful for improving evaluation procedures. The ETE Test team improved its data collection and analysis processes as a result of experiences from the functionality and integration and risk reduction tests.

5.2.1.5 Command and Control

- Have test controllers who are extremely familiar with the test and network configuration. The Phase 4 test succeeded partly because it had an experienced test controller with the necessary tools to evaluate problems and the authority to make meaningful decisions regarding test problems.

- Have a centralized test control center. The JADS TCAC is configured to allow for convenient, instant communications with all the nodes. It acted as the central point of contact between the nodes and for all problems. The test controller kept track of test progress and documented any problems that occurred.

- Establish control over resources. Linking various facilities using ADS can require significant development of facility interface hardware and software.

- Distributed tests require personnel distribution. When many distributed nodes are required for the successful completion of a test, personnel will need to be located at these nodes. The complexity and input an individual node contributes should guide the assignment of personnel. The ETE Test Phase 4 required several people at the Fort Hood, Northrop Grumman and TCAC nodes; only one person was needed at the White Sands node. The Fort Sill node used only resident personnel.

5.2.2 Policy

- Network management and troubleshooting must be disciplined and organized with a thorough understanding and strong configuration control of the ADS network.

5.2.3 Personnel

- Personnel involved in a distributed test should understand the "big picture." When people are geographically separated, it becomes easy for them to focus on their own individual portion of the test. When problems arise, personnel who understand the entire test and the overall network will find solutions much faster.

6.0 Conclusions/Recommendations

6.1 Utility

6.1.1 Utility Conclusions

6.1.1.1. Enhanced Testing. An ADS-enhanced live test environment can enhance the testing of C4ISR systems.

- The Phase 4 test showed that ADS technology can realistically represent a C4ISR system enabling the system's users to collect valid and useful operational information.

- Compared to conventional methods, an ADS-enhanced live test environment can realistically test C4ISR systems:

  - with larger numbers of ground-based entities at a much lower cost.

  - with more control over the specific aspects of the scenarios being tested. Using ADS, the test director is not at the mercy of a training exercise over which he/she has no direction. Rather, the test director can control the simulated entities.

  - for longer periods of time enabling increased data collection and the ability to analyze and improve the data gathering process.

  - under realistic but unsafe conditions, such as convoy vehicles driving across rugged terrain under wartime conditions.

- By allowing the simulation of large battlespaces with large numbers of entities, ADS technology provides testers with greatly expanded capabilities for test concept and design.

- Testers can use ADS to save time, resources and test personnel man-hours by linking several pieces of equipment and/or facilities together for simultaneous testing instead of conducting individual tests at different locations.

- ADS technology provides access to elements participating in the test from their normal work locations, greatly reducing the additional operational tempo required to support both testing and test integration, training and rehearsal.

6.1.1.2 Improved Opportunities for Training. If an ADS environment is developed for testing, the same environment can easily be modified and transitioned to the training world. ADS technology can then improve opportunities for training with a C4ISR system.

- Conventional training can be limited by the availability of those assets making up the C4ISR system's operational environment. ADS technology, by simulating those key assets, can provide longer periods of time for realistic operation of the C4ISR system.

- C4ISR system operators can take advantage of the additional training time provided by ADS technology to confirm current tactics and to test "what if" scenarios and new tactics.

- A C4ISR simulation incorporated into an ADS environment can enhance operator training by providing useful information on the battlefield surveillance and the targeting process. It can also help the battle manager by providing a high-level picture of the entire battlefield and aiding in the effective allocation of battle resources.

- An ADS environment can provide testers and C4ISR system operators with the opportunity to check the interoperability and compatibility of the equipment.

- ADS simulations can help C4ISR system operators familiarize themselves with the maneuver tactics of foreign armed forces – valuable experience for possible future deployments.

- C4ISR system operators can train in an operational environment with multiple assets using the capabilities of ADS technology to tie several pieces of equipment and/or facilities together and to simulate large numbers of fielded vehicles and associated personnel. In contrast, conventional training would provide far fewer assets in the operational environment, if any at all.

6.1.2 Utility Recommendations

- Large exercises could use the ETE Test environment to virtually augment the battlefield with simulated targets. During Phase 4, this capability was demonstrated with the integration of a live E-8C Joint STARS aircraft into the ETE Test ADS environment.

- An ADS-enhanced live test environment, like the ETE Test environment, is flexible enough to allow for further expansion and increased opportunities for testing C4ISR systems. The Janus battlespace can be expanded as required. Increasing the number of LGSMs or common ground stations (CGSs) would create more realistic targeting capabilities. By adding other assets to the environment, such as an unmanned aerial vehicle (UAV) or a tactical aircraft simulator, the robustness of the environment could be significantly enhanced.

6.2 Technical

6.2.1 Technical Conclusions

- The ETE Test Phase 4 WAN required only a small portion of the available bandwidth. This indicates that a much higher packet rate could be applied to ADS testing without causing bandwidth problems. The satellite link, however, limited the packet rate available for live testing. This required modifications to the DIS standard (no heartbeat and creation of VDPs) and may not be acceptable in all instances. The weakest link, or in this case the smallest, must be identified and the test designed to accommodate it.

- The ETE Test network was highly reliable and stable during the Phase 4 test.

- The ETE Test team's extensive risk reduction testing played an important role in eliminating the presence of major ADS system failures during Phase 4 testing. Many ADS problems were identified and resolved during this risk reduction period, thus minimizing their potential for affecting the actual testing. As a result, the ADS problems noted in Table 9 had only a minor impact on Phase 4 testing and caused only brief delays or reductions in capability.

6.2.2 Technical Recommendations

- With careful planning and resource management, testers can address the issues associated with integrating simulations into an ADS test environment. They can also identify the assumptions and limitations associated with those simulations.

  - Budget, schedule, and provide the manpower necessary to develop the simulations. Simulation development is typically labor intensive and thus costly.

  - Determine the level of simulation detail needed for the ADS test. Development costs are directly related to the level of simulation detail.

  - Identify and provide training for the users of the simulations.

6.3 Infrastructure

6.3.1 Infrastructure Conclusions

- ADS can reduce the number of troops and associated equipment involved in tests because of its simulation of fielded forces. However, the ADS infrastructure requires technical personnel to set up and execute the tests and to analyze the test results.

- Highly structured test control is a key ingredient for ADS test success. This test control should include formalized procedures with an emphasis on checklists.

- An ADS test can't always count on having the personnel requirements for a distant node supplied by an organization local to the node. Even if an ADS test is able to employ these people, it may then lose them to other activities deemed more important by the local organization.

- An ADS-enhanced live test environment necessitates sophisticated instrumentation with rigorous processing speed, data storage, and data integration capabilities. This instrumentation can be costly and can require trained personnel for its successful operation.

- Distributed testing typically means distributed personnel and distributed equipment. Distributed personnel lead to high travel costs. Equipment located at distant network nodes will still require maintenance either through contracts or trips by a network engineering team.

- ADS analysts must have a well-planned and organized approach to managing the large amounts of data produced from ADS testing.

6.3.2 Infrastructure Recommendations

- Make every effort to simplify the infrastructure. Time spent in the planning stages of an ADS test, with an emphasis on reducing the complexity of the test network, is time well spent. Use proven hardware and keep it the same wherever possible.

- Keep in mind the disadvantages, as well as benefits, of the networked nature of an ADS environment. The ADS tester will almost always be dependent upon a telecommunications provider.

Appendix A – JADS Test Procedures

A1.0 Test Procedures

Various types of checklists were used during the execution of the Phase 4 test. The Test Control and Analysis Center (TCAC) test controller checklist can be found in Section A1.1, *TCAC Test Procedures*. This checklist was used to ensure network and logger functionality and to provide overall test control procedures. Each node (White Sands Missile Range [WSMR], Northrop Grumman, and Fort Sill) incorporated the logger functions from the TCAC checklist into their own checklist.

Other checklists were used to direct the operation of various pieces of test equipment. An example is included in Section A1.2, *TCAC Plan View Display (PVD) Procedures.*

Section A1.3, *WSMR Procedures*, is representative of the site-specific checklists. WSMR, Northrop Grumman and Fort Sill all developed procedures for operation of the End-to-End (ETE) Test environment equipment. Only Fort Hood, the only site without a logger, failed to develop written procedures. Their procedures were primarily accomplished by the resident specialists who have their own procedures.

A1.1 TCAC Test Procedures

The following are the written test procedures used in the TCAC during Phase 4 testing.

72 HOURS PRIOR TO TEST

Network Coordinator: ______________________

Date: ___________ Test Time: ___________ to ___________

1 ________ Check supplies.

2 Turn on equipment.

________ a. Turn on 3 Barcos (Spectrum [Sun5] on 1, Janus [hp735] on 2, and NetVis [indigo2] on 3).

________ b. Log in as "root" to **indigo2** in the TCAC, and **indy4** in communications room 1.

________ 1) From the toolchest, select Toolbox, JADS Toolbox, Monitor, PDU Monitor, PDU Statistics, Show Stats to display protocol data units (PDUs).

________ 2) From the toolchest, select NetVis, NetGraph-ETE to display network traffic.

________ 3) From the toolchest, select NetTests, Status Check ETE to start and display network connectivity tests. (**uts** in comm rm 1 pings **wsmr, ftsill**, and **fthoodafatads**. **indigo2**, pings, **grumman**, **indy3**, and **sparc5** at Ft Hood).

________ c. In the TCAC, run Spectrum on the **Sun20** (server) and **Sun5** (graph) to display Zulu time and router status.

d. Create an empty file "`touch /scripts/.go`" in grumman, indigo2, and indy4.

3. ________ Clear router interfaces. To clear the **grumman_router**, **jads_router**, and **fthood_router** from **indigo2**; and **fthood_router**, **ftsill_router**, and **wsmr_router** from indy4, run: "`/scripts/clear_router ete.`"

4. ________ Not used.

5. ________ Time accuracy. Verify that each site has network time protocol (**NTP**) running.

   a. From **uts**, run "`/scripts/check_time`" and verify that the offsets for **ftsill** and **wsmr** are less than 1 millisecond (ms).

   ________ b. From **indigo2**, rlogin to **indy1**, run "`/scripts/check_time.`" Verify offsets for **grumman**, **indy3**, and **sparc5** are less than 1 ms.

6. ________ Available disk space. Verify that each logger has at least **600 megabytes (MB)** of unused disk space available on the **/disk2** partition.

   a. From **uts**, rlogin to **ftsill** and **wsmr,** in turn, and from **indigo2**, rlogin to **grumman**, and **indy3**, in turn.

   ________ b. Run "`df -k`" on each machine (including **uts**) to display the available disk space. Verify that each has at least **600 MB** available.

7. ________ Port settings. Verify that each logger is set to port **3000** and the exercise identification (ID) is **0**.

   a. From **uts**, rlogin to **ftsill** and **wsmr,** in turn, and from **indigo2**, rlogin to **grumman**, and **indy3**, in turn.

   ________ b. Run "`more /scripts/dt_logger`" to view the file. Look for the entry: "`/usr/local/bin/jads_logger 3000 0 /disk2/logfiles /$testdate"_test"$testnum"_"$runnum"_"$site".log"`" entry in two places.

8. ________ Voice conference net. Verify the net is functional by dialing in from two different phones in the TCAC at the same time to establish the net.

9. ________ Not used.

10. ________ Data collection test a:

   a. From **uts**, rlogin to **ftsill** and **wsmr,** simultaneously, and from **indigo2**, rlogin to **grumman**, and **indy3**, simultaneously.

   ________ b. Start the **ftsill**, **grumman**, **indy3**,and **uts** loggers using test number "`000`" and run number "**a**" (i.e. - "`/scripts/dt_logger 000 a`").

   ________ c. Run the "`/scripts/run_player 3000 /disk2/logfiles/ne_test.log`" file on the **wsmr** machine.

   ________ d. Determine when run is complete. Stop all loggers ("`Ctrl-C`").

   ________ e. Check digital communications terminal (DCT) results. Verify reception of **2281** PDUs on **grumman**, **indy3**, and **uts** (or **indy4**) loggers. (No PDUs at **ftsill**).

1 Data collection test b:

1________ a. From **uts**, rlogin to **ftsill** and **wsmr,** simultaneously, and
. from **indigo2**, rlogin to **grumman**, and **indy3**, simultaneously.

________ b. Start the **grumman**, **indy3**, **uts** and **wsmr** loggers using test number "`000`" and run number "`a`" (i.e. - "`/scripts/dt_logger 000 a`").

________ c. Run the "`/scripts/run_player 3000 /disk2/logfiles/ne_test.log`" file on the **ftsill** machine.

________ d. Determine when run is complete. Stop all loggers ("`Ctrl-C`").

________ e. Check DCT results. Verify reception of **2281** PDUs on **grumman**, **indy3**, and **uts** loggers.

12.________ Report the results of the network checks to the test controller. Supervise repairs as necessary to prepare equipment for the test sequence.

PRETEST (DAY OF TEST)

Network Coordinator: ____________________

Date: __________ Test Time: __________ to __________

1.________ Check supplies. Provide checklists, blank log sheets, file name lists, pens, pencils, scratch paper, and 4 millimeter (mm) tape cartridges for the test.

2. Turn on equipment.

________ a. Turn on 3 Barcos (Spectrum [Sun5] on 1, Janus [hp735] on 2, and NetVis [indigo2] on 3).

________ b. Log in as "root" to **indigo2** in the TCAC, and **indy4** in communications room 1.

________ 1) From the toolchest, select Toolbox, JADS Toolbox, Monitor, PDU Monitor, PDU Statistics, Show Stats to display PDUs.

________ 2) From the toolchest, select NetVis, NetGraph-ETE to display network traffic.

________ 3) From the toolchest, select NetTests, Status Check ETE to start and display network connectivity tests. (**uts** in Comm Rm 1 pings **wsmr, ftsill**, and **fthoodafatads**. **indigo2**, pings, **grumman**, **indy3**, and **sparc5** at Ft Hood).

c. In the TCAC, run Spectrum on the **Sun20** (server) and **Sun5** (graph) to display Zulu time and router status.

3.________ Clear router interfaces. To clear the **grumman_router**, **jads_router**, and **fthood_router** from **indigo2**; and **fthood_router**, **ftsill_router**, and **wsmr_router** from indy4, run: "`/scripts/clear_router ete.`"

4.________ Not used.

5. ________ Time accuracy. Verify that each site has **NTP** running.

________ a. From **uts**, run "**`/scripts/check_time`**" and verify that the offsets for **ftsill** and **wsmr** are less than 1 ms.

________ b. From **indigo2**, rlogin to **indy1**, run "**`/scripts/check_time.`**" Verify offsets for **grumman**, **indy3**, and **sparc5** are less than 1 ms.

6. ________ Available disk space. Performed at each logger by the logger operator.

7. ________ Port settings. Performed at each logger by the logger operator.

8. ________ Join the voice conference net. Both the test controller and the network coordinator (NC) dial **61143** in the TCAC to establish the conference net.

9. ________ Time synchronization. **ftsill**, **grumman**, **indy3**, and **wsmr** operators check global positioning system (GPS) time reception by typing "**`date`**" and press **Enter** on the NC's mark. Report time to NC.
(NOTE: **indy1** is time server for classified, **uts** is time server for unclassified.)

10. Data collection test a:

________ a. Cue **ftsill**, **grumman**, **indy3**,and **uts** operators to start loggers using test number "**`000`**" and run number "**`a`**" (i.e. - "**`/scripts/dt_logger 000 a`**").

________ b. Cue **wsmr** operator to run "**`/scripts/run_player 3000 /disk2/logfiles/ne_test.log`**" file.

________ c. Determine when run is complete. Cue all operators to stop loggers ("**`Ctrl-C`**").

________ d. Check DCT results - Have **grumman**, **indy3**, and **uts** operators verify reception of **2281** PDUs. (No PDUs at **ftsill**).

11. Data collection test b:

________ a. Cue **grumman**, **indy3**, **uts**, and **wsmr** operators to start loggers using test number "**`000`**" and run number "**`b`**" (i.e. - "**`/scripts/dt_logger 000 b`**").

________ b. Cue **ftsill** operator to run "**`/scripts/run_player 3000 /disk2/logfiles/ne_test.log`**" file.

________ c. Determine when run is complete. Cue all operators to stop loggers ("**`Ctrl-C`**").

________ d. Check DCT results - Have **grumman**, **indy3**, **uts**, and **wsmr** operators verify reception of **2281** PDUs. (No PDUs at **ftsill**).

12. ________ Report the results of the network checks (items 9-11) to the test controller.

The pretest phase is now complete. Proceed to the test run phase.

NOTE: Sometimes the logger process does not terminate on the **grumman** logger. In that case, run **`/scripts/find_logger`** on the **grumman** logger to kill the process and delete the old log file before restarting the logger with the same filename.

TEST RUN

Network Coordinator: ______________________

Date: ___________ Lab Time: ___________ to ___________

1. ________ Start loggers. Obtain the test and run numbers from the test controller and record on the log sheet. Operators are cued by the test controller when to start loggers. Record start time on the log sheet.
   ________ a. Early in the test run, verify with operators that all loggers are receiving PDUs (number is increasing.
   ________ b. Periodically check with operators that all loggers continue to receive PDUs (number is increasing).
   ________ c. Periodically check "bat" phone operation if not used regularly.
   ________ d. Every ½ hour, run a time accuracy check. From **uts**, run "**`/scripts/check_time`**" to check **ftsill** and **wsmr**. From **indigo2**, rlogin to **indy1** and run "**/scripts/check_time**" to check **`indy1`**, **grumman**, and **tcacindy**. Time offsets should be **<1** ms.
   ________ e. Keep written event log.

2. Stop loggers. Loggers stop recording data when directed by the test controller ("**Ctrl-C**").
   ________ a. Record the stop time and the total number of PDUs from each logger on log sheet.
   ________ b. Confirm that the required data have been logged. From **uts**, rlogin to **ftsill** and **wsmr** and run "**`ls -l /disk2/logfiles.`**" From **indigo2**, rlogin to **indy3**, and **grumman** and run "**`ls -l /disk2/logfiles`**." Check the file sizes; the filename is "***mmddyy_test#-run#_loggername*.log.**"

3. ________ Subsequent runs. When additional runs are required, repeat steps 1 and 2 for each run.

The test run phase is now complete. Proceed to the post-test phase.

POST TEST (DAY OF TEST).

Network Coordinator: ______________________

Date: ___________ Test Time: ___________ to ___________

1. Remote file capture. Consolidate, compress, and copy the test run logger files from each remote site.
   ________ a. For classified data, rlogin to each logger (**grumman** and **indy3**), in turn, from **tcacindy** in the TCAC, or
   For unclassified data, rlogin to each logger (**ftsill**, **wsmr**, and **uts**), in turn, from **uts**.
   ________ b. If only 1 file for the day exists in the logger at a site, skip to step c. If more than 1 log file for the day exists at a site, consolidate them by using the command
   "**`tar cvf mmddyy_sitename.log.tar mmddyy*.log`**"
   where * is the wildcard character that includes all the files for that day for that site name.

(e.g., - "**`tar cvf 040798_wsmr.log.tar 040798*.log`**").

_________ c. Compress the single log file (e.g., - "**`compress 040798_wsmr.log`**") or the tar file from step b ("**`compress 040798_wsmr.tar`**").

_________ d. On **tcacindy**, run "**`/scripts/rcp_etefile`**" to copy the tar'd and compressed classified files ("***mmddyy_sitename*.log.Z**") from both **grumman** and **indy3** loggers to **tcacindy:/disk2/ete/*mmddyy*/.**

_________ e. On **uts**, run "**`/scripts/rcp_etefile`**" to copy the tar'd and compressed unclassified files ("***mmddyy_sitename*.log.z**") from **ftsill**, **uts**, and **wsmr** loggers to

_________ **uts:/disk2/ete/*mmddyy*/.**

_________ f. Copy the unclassified files from step e to 4mm tape and activate the write protect feature.

g. Move the tape to **tcacindy** and copy the unclassified files from the tape to **/disk2/ete/*mmddyy*/** (i.e., from the **ete** directory, run **`tar xv`** to extract the files from the tape to the hard drive). **Make sure the write protect feature is ON.**

2 Backup tapes.

_________ a. Create a backup tape of the files in **tcacindy:/disk2/ete/*mmddyy*/** using either the "**`tar cv mmddyy`**" command while in the **ete** directory (or the tape tool on the **tcacindy** desktop).

b. Verify the backup using either the "**`tar tv`**" command or the tape tool.

_________ c. Remove the tape from the drive and label it.

_________ d. Repeat a, b, and c to create a duplicate tape.

_________ e. Deliver both tapes to the ETE Test team representative.

3_________ Delete the data collection test and the backed-up log files from **/disk2/logfiles/** on all loggers.

4_________ On the last day of testing, delete the file "**`/scripts/.go`**" in grumman, indigo2, and indy4.

5_________ Logoff from logger. Turn **Off** the monitor, but leave the central processing unit (CPU) **On**!!!

6_________ Participate in mission debrief, if applicable.

A1.2 TCAC Plan View Display (PVD) Procedures

The following procedures were used to initiate test monitoring with the Janus Plan View Display program. This is representative of the specific checklists developed to aid in the operation of test equipment.

Functionality/Integration Test Checklist
(TCAC-PVD)

Date: ______________________
Scenario: ______________________

Test Start Time (z): ____________ Test Stop Time (z): ____________
Scenario Start Time: ____________ Scenario Stop Time: ____________

Step #	POC	Action	Event	Go/No Go
Run PVD				
1	ETE	Power on the hp735 monitor. Log on to the hp735 as **hovey**.		
2	ETE	From the xterm window that appears, type *pvd*, and hit ***enter***.	Use this alias to start Janus plan view display.	
3	ETE	From the Janus plan view display menu, verify the parameters for the run: Workstation ***1*** Terrain File _____ Screen File _____ Symbol File ***3*** Symbol Size ***10*** Terrain File Meridian ***45*** Exercise ID ***BLANK*** Map Spheroid ***1*** Mode ***BLANK*** Terminate this Run ***N*** and hit ***keypad enter***.	Use the correct terrain file and screen file for the vignette.	
4	ETE	Wait until the PVD terrain and combat systems databases are loaded.	Last message: Opening file *../jads_ete/trn/TSCRN__. DAT*	

5	ETE	Double click the *Analyst_Workstation_WS1* icon to bring up the scenario window.		
6	ETE	From the *Analyst_Workstation_WS1* scenario window, functions menu, left click **Draw CAC**.		
7	ETE	From the *Analyst_Workstation_WS1* scenario window, CAC File menu, select the CAC file number to display. Left click increases number, and right click decreases number. Left click **Add** to display the CAC.	Places command and control overlays on the scenario box.	
8	ETE	From the *Analyst_Workstation_WS1* scenario window, function menu, left click **Display**.	Ready to receive and display DIS PDUs.	
9	ETE	From the *Analyst_Workstation_WS1* scenario window menu: Left click any **tick** on the zoom in/out menu, then select the desired zoom point on the scenario box. Left click **CAC**. Left click **Display**. Left click **Clear**.	Used as necessary to zoom in/out of the scenario box. Used as necessary to add or remove the command and control overlays which have been added in step 7. Used as necessary to start or stop Janus plan view display from receiving PDUs. Used as necessary to clear any text or information displayed on the scenario	

			box. NOTE: A particular function is active when highlighted.	

Step #	POC	Action	Event	Go/No Go
Stop PVD				
1	ETE	From the *Analyst_Workstation_WS1* scenario window, right click **End**.	Shuts down PVD.	
2	ETE	Minimize the *Analyst_Workstation_WS1* scenario window.	In the xterm that remains, verify this message: STOP -----JANPVD Program Terminated-----	
3	ETE	From the *Analyst_Workstation_WS1* icon, right click and choose close.	Closes the scenario window.	

Step #	POC	Action	Event	Go/No Go
Shut Down Test				
1	ETE	Left click **EXIT** from the HP VUE front panel.	Signs off the hp735.	
2	ETE	Left click *Continue logout* from the dialog box.	Confirms desire to log out.	
3	ETE	Power off the hp735 monitor.		

A1.3 WSMR Procedures

This checklist is representative of the individual site checklists. It incorporates the logger functionality and the site specific actions required by the operator(s). These are maintained by the site specialists and updated as changes are required.

Functionality/Integration Test Checklist
(WSMR)

Date: ____________________
Scenario: ____________________
Janus File: ____________________
Indy File: ____________________

Test Start Time (z): ____________ Test Stop Time (z): ____________
Scenario Start Time: ____________ Scenario Stop Time: ____________

Step #	POC	Action	Event	Go/No Go
Network Activation				
1	ETE and N&E	Verify operation of hotlink phone. If no go, contact N&E to fix the network.	Enables secure and unclassified voice communications.	
2	ETE and WSMR	Verify that WSMR indy and the WSMR hp715 are on the JADS ETE network.	Initial step in ensuring network is operational.	
3	N&E	Verity N&E has cleared and reset routers.	Clears router interface cards.	
4	ETE	Power on the WSMR monitor. Log on to WSMR as **dislog**. From a Unix shell window as **su**, run */scripts/restart*.	Restarts the indy.	
5	ETE	After a successful restart, log on to wsmr as **dislog**.	Signon is used for checking network communications and logging PDU data.	
6	ETE	From a Unix shell window as **su**, run */scripts/ping_test* to get ping statistics for each remote site.	Verifies that each network link is operational. 3% loss at Fort Sill and uts is normal.	

7	ETE	From a Unix shell window as **su**, run */scripts/check_time.*	Displays the offset from uts. Should be less than 1 ms.	
8	ETE	From a Unix shell window as **su** and at the test controller's direction, run */scripts/run_player 3000 /disk2/logfiles/ne_test.log* to check ability to send PDUs to each remote site.	Verifies sending 2281 PDUs and receiving the same number of PDUs at each remote site.	
9	ETE	From a Unix shell window as **su** and at the test controller's direction, run */scripts/dt_logger* _____ _____ to check ability to receive PDUs from a remote site. At the test controller's direction, hit **Ctrl-C** to end the log file.	Verifies receiving 2281 PDUs from a remote site.	
10	ETE	From a Unix shell window, *cd /usr/local/bin* and run *./display_pdu_rate.* Select port ***3000 0.*** Left click ***start***.	Verifies that PDU_rate = 0. Ensures that there aren't any DIS communications before the start of testing.	

Step #	POC	Action	Event	Go/No Go
Start WSMR Logger				
1	ETE	From a Unix shell window as **su** on WSMR, run */scripts/dt_logger* _____ _____	Script that runs the JADS logger.	
2	ETE	Verify the log file name as */disk2/logfiles/___________wsmr.log* and port 3000.	Opens port 3000 to listen and log all DIS communications. Writes to the listed log file.	

Step #	POC	Action	Event	Go/No Go
Start Janus				
1	ETE	Power on the c180 monitor. Log on to the c180 as **JADS.**		
2	ETE	From an hpterm window, type ***janus.exe***, and hit ***enter***.	Use this executable to start Janus.	
3	ETE	Left click ***PE*** (Program Execution) from the Janus User Options menu.	Brings up the Program Execution menu.	
4	ETE	Left click ***JE*** (Janus Execution) from the Program Execution menu.	First step in defining the scenario.	
5	ETE	Type desired scenario number _____ for the run, and hit ***enter***. Type run number *1*, and hit ***enter***.	Tells Janus which scenario to run.	
6	ETE	Hit ***enter*** again to continue.	Ready to continue.	
7	ETE	Verify that ***1*** is entered. Hit ***enter*** one more time.	Use a normal run.	
8	ETE	From the Janus Runtime Screens menu, left click ***11***. Verify time of day is correct for the vignette, and hit ***keypad enter***.	Verifies time of day.	

9	ETE	From the Janus Runtime Screens menu, left click ***22***. Verify that there is a setup for: *WS Number 1*,and *Side 1*, and hit ***keypad enter***.	Verifies that a controller workstation has been configured.	
10	ETE	From the Janus Runtime Screens menu, left click ***66***. Verify the DIS operational parameters for the run: Janus side ***1*** DIS side ***2*** DIS COMM calls/sec _______ Units processed/COMM call _______ Terrain File Meridian (+E) ***45*** Heartbeat(s) _______ Dead Reckoning Threshold ***999*** Site ***TRAC-WSMR 23*** Host CPU ***HP 4*** Exercise ***JADS-ETE 4*** DIS version transmit ***4*** DIS version receive ***4*** and hit ***keypad enter***.	Verifies DIS parameters. Calculate the new heartbeat as follows: $C \times R \times H \leq T$ where C = calls/sec, R = units/call, H = heartbeat, and T = total number of units in scenario	
11	ETE	Left click ***JJ*** (Begin Janus) from the Janus Runtime Screens menu.	Loads the Janus scenario.	
12	ETE	Wait until the Janus scenario loads. Verify: Scenario number _________ Total number of units __________		
13	ETE	Double click the *side1* icon to bring up the scenario window.	This brings up the scenario window which allows a Janus operator to interact (game) the exercise.	

Step #	POC	Action	Event	Go/No Go
Run Scenario				
1	ETE	From the *side1* scenario window, left click ***DIS***.	DIS button highlights. Opens DIS communications.	
2	ETE	From the *side1* scenario window, left click ***START***.	First step in running a Janus scenario.	
3	ETE	Minimize the Janus scenario window (*side1*). Type ***rr*** in the Janus window, and hit ***enter***.	Ready to continue the Janus run.	
4	ETE	Type ***n*** and hit ***enter***.	No planned save.	
5	ETE	Hit ***enter*** again.	Default checkpoint frequency.	
6	ETE	Double click the Janus scenario window (*side1*).	Verifies scenario movements and a running time of day counter.	
7	ETE	Verify that loggers are logging.		

Step #	POC	Action	Event	Go/No Go
Stop Scenario				
1	ETE	From the *side1* scenario window, left click ***DIS***.	DIS button unhighlights. Closes DIS communications.	
2	ETE	From the *side1* scenario window, right click ***ADMIN***.	Brings up options menu.	
3	ETE	Left click ***EJ*** (End Janus).	Quits the scenario run.	
4	ETE	Right click 2 times.	Completely closes Janus.	
5	ETE	Left click EXIT from the HP VUE front panel.	Sign off the hp715.	

Step #	POC	Action	Event	Go/No Go
Shut Down Test				
1	ETE	Power off the c180 monitor, and shutdown CPU.		
2	ETE and N&E	Make sure that JADS N&E FTP */disk2/logfiles/___________wsmr.log* back to JADS and place the file in ***/usr/testdata2/logs/ete/DDMMYY***	Ensures data integrity. This file will be analyzed by JADS analysts.	
3	ETE	Power off the wsmr monitor.		
4	ALL	After-action review		

Appendix B
Joint STARS Multiservice Operational Test and Evaluation
Phase 4 Measures Correlation

August 1999

Appendix B
Pages 91-98
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Appendix C – TEXCOM Test Simulation Development Report

C1.0 Introduction

The U.S. Army Test and Experimentation Command (TEXCOM) Technology Laboratory (TTL) was selected to develop the scenario and provide scenario support for the Joint Advanced Distributed Simulation (JADS) Joint Test Force End-to-End Test. All elements of TTL, government and TTL support contractors assisted in supporting the JADS project at appropriate times in the process.

C1.1 Report Requirement

Task Number 9200.1, Fiscal Year (FY) 99 JADS Work Authorization Order, delineates the requirement for this report.

C1.2 Scenario Development Environment

TTL support analysts assisted JADS test team members with test simulation design from early concept development through final simulation preparation. The scenario support analysts assisted with adjustments to the simulation and facilitated use of the simulation tools during the live test phases. The active exchange among test team members and the TTL scenario support cell fostered full communication and a common understanding of test scenario issues. This positive, professional environment created common understanding and trust and kept the scenario development and support focused.

C1.3 Report Objectives

- Record the scenario development process as planned and as evolved.
- Assess the scenario development process and recommend improvements for use if there is a future related requirement.
- Examine the scenario development process to determine what parts may be assisted with automation.

C2.0 Test Simulation Support Methodology

C2.1 Set Simulation Conditions

C2.1.1 Develop *The Road to War*

The environment and circumstance for a simulated conflict was set in *The Road to War* document. Users were provided background for events leading to the notional conflict and a description of the ensuing battle. The scenario was adapted from the U. S. Army Command and General Staff College (CGSC) Common Teaching Scenario Southwest Asia, dated April 1992, as modified by Training and Doctrine Command (TRADOC).

C2.1.2 Prepare Simulation Support Documents

Several key documents were developed to facilitate and manage corps battle simulation (CBS) game play. They were necessary to define the forces played and to provide a sound, structural basis for adaptations and adjustments that would occur during the use of the scenario in the various test phases.

C2.1.3 Force Hierarchy

The red force hierarchy was adapted from the Advanced Tactical Command and Control System (ATCCS) common scenario and developed in detail sufficient to support the test. The blue force hierarchy included U. S. III Corps units plus coalition forces and an additional U. S. division, all represented as brigade-size icons. Red forces were shown both as large units and as units broken down to smaller fighting elements as needed to depict the resolution necessary for the test. The precise delineation of the force hierarchy was so each unit could be tagged and so all movements and actions could be tracked in the game.

C2.1.4 Supporting Units

All units had to have a supporting unit specified. The CBS logistical supply process requires the supporting units to serve as flow points for resources to their respective units as may be needed.

C2.1.5 Unit Templates

Unit templates were prepared for all different unit types and sizes. The templates showed the unit personnel structure, the equipment list and associated unit resources. Each template was coded so it could be assigned to all like units.

C2.1.6 Start Locations

All units had to be assigned starting locations at game start to set the battle picture. The units were arrayed within the control lines of the respective forces as shown in both red and blue operations orders.

C2.1.7 Unit Strength Percentage

All units were set at a force strength that might be reasonably expected for the start of the conflict. Once the conflict started, strength levels changed through normal consumption, resupply or battle attrition. Resupply was conducted by established CBS game rules.

C2.1.8 Prepare Operations Orders for Red and Blue Forces

Operations orders (OPORDs), including selected annexes, were written for both the opposing and friendly forces. They were used for orientation to the anticipated operation and for a common understanding of the battlefield parameters in preparation for developing the CBS game tape.

C2.1.9 Build Corps Battle Simulation Game Tape

The CBS game tape was built in the TTL in December 1997 and January 1998. The team assembled to build the game tape was CBS-trained TTL support contractors and professional CBS trainers/coaches/players from III Corps Battle Simulation Center. All the support documents were assembled as working manuals and provided to all team members. The TEXCOM team members were assigned to manage blue forces during the tape build. The CBS team members were assigned to manage the red forces. The red forces would be deployed in finer resolution, as the focus of the test would be on the opposing forces. Some of the test segments would focus on rear area logistics and others on the movements of committed line combat units.

C2.1.10 Train CBS Workstation Operators

All the workstation operators were versed in CBS game procedures. The limited training was tailored to individual workstation assignments. Operators were assigned to maneuver combat units, artillery, logistics forces and air defense. With areas of responsibilities assigned, all the operators studied support documents and their respective tasks so they could play the game in a coordinated manner.

C2.1.11 Deploy Forces in CBS

All the forces for blue and red programmed into the game had to be moved to the planned start locations. With the number of units that had to be deployed, the initial force deployment took the major part of a week.

C2.1.12 Validate Force Structure

After forces were assigned to preplanned start locations, all the units were checked for proper military tables of organization and equipment. Tactical locations of units were double checked for specific location and for tactical relationship with adjacent units.

C2.1.13 Compile 128-Hour CBS Tape

With all parties prepared and forces positioned for game start, the tape build began. The CBS game play was governed by a detailed force synchronization matrix that showed what combat maneuver was expected at what time. It also showed the expected actions of supporting forces of all varieties. This matrix served as a script for the tape build. Some lead-time start-up was needed each day. With that consideration, the team worked to build from six to eight hours of finished CBS game tape each day. Downtime was kept to a minimum, and the build progressed as planned.

C2.1.14 Monitor Intelligence Collection Devices

The Joint Exercise Support System Intelligence Module (JIM) was used to collect intelligence of all types from the game as the game build was in progress. A special JIM team linked its collection program to CBS and provided a parallel stream of intelligence messages that would normally be expected during actual tactical operations. Those messages were prepared for dissemination during the actual test to feed the test unit player cell with a realistic flow of intelligence. Those messages would be combined with information from the test Joint Surveillance Target Attack Radar System (Joint STARS) aircraft to formulate intelligence targeting recommendations to the tactical battle captains. The intelligence information presented through the JIM system was less than 100 percent of what was actually happening, as would normally be expected in an actual conflict.

C2.1.15 Validate CBS Tape

The CBS game tape was reviewed in detail. The review was conducted to search for anomalies in the tape to ensure no errors had been introduced that placed units in illogical locations and that there were no gaps in JIM sensor coverage. Several gaps were found in the JIM products and data were developed to fill those gaps.

C2.1.16 Prepare Vision XXI to Facilitate Game Truth Capture

Vision XXI, developed by Tapestry Solutions, Inc., is a real-time exercise monitoring tool that provides a highly effective visual interface to track current and historical battle conditions. It has the capability to watch individual unit movement and resource status. The 128-hour game tape was loaded into a Vision XXI workstation. By using the historical mode, analysts were able to examine all phases of the portrayed battle at will in varied force resolution and determine locations and times of activity that could best be used for test purposes.

C2.2 Establish Ground Reference Coverage Areas (GRCAs)

The TTL scenario support team lead and the JADS project officer jointly selected GRCAs. First, Joint STARS system experts and the test team selected orbital flight paths. They considered potential threats against the aircraft and worked to select optimal tracks to cover the test terrain area. Then the GRCAs were plotted as they considered appropriate orbit tracks for the aircraft and the various types of battlefield action that would best be used to support the different test objectives. Three different orbits were set and the associated GRCAs were plotted so there could be coverage of different areas of the battlefield. The GRCAs were oriented parallel to the flight orbits. Both CBS and Janus game portrayal boxes are north-south, east-west. The GRCAs were set at an angle to the game boxes. The resulting misalignment increased the complexity of converting data from CBS to Janus.

C2.3 Identify Vignette Periods

Nine different six-hour periods were selected to focus on different battle phases and different types of combat force and combat support activity. The synchronization matrix used during the game tape build helped as a guide, but to fully examine activity in detail, the total recorded game had to be examined. The CBS game tape was loaded on the Vision XXI workstation. With this setup, analysts could step through the game in time increments or examine game activity in specified time blocks. With a list of activity types best suited for test purposes, appropriate six-hour time blocks were identified.

C2.4 Provide CBS Data for Conversion to Janus

The CBS system is an aggregate-based simulation. Symbols of military units displayed represent all the people, equipment and other resources associated with that unit. Status of units can be determined by querying the CBS game. The Joint STARS sensors are built to see individual pieces of equipment not unit icons. Janus is an entity-based game; it sees individual pieces. For the Joint STARS sensors to function in relationship to the test scenario, the data about the forces played needed to be converted from an icon base to an entity base. The movement tables that showed movements of all the red forces throughout the recorded CBS game were extracted and taken to Janus programmers at the U.S. Army Training and Doctrine Command Analysis Center (TRAC), White Sands Missile Range (WSMR), New Mexico.

The process of preparing the data for the Janus programmer involved several people and took several weeks to complete. A TTL programmer worked with the CBS database and pulled information in ten-minute intervals on all units that moved. The Janus programmer needed all unit data arranged hierarchically showing initial movement and subsequent movements. Other data sets reflected logistics deltas, unit location deltas, radar unit deltas, air defense deltas and unit equipment deltas. After identifying all unit data in the respective GRCAs, the data were converted to rich text format so they would be transportable.

The TTL scenario team lead worked directly with the Janus programmers to begin the process of converting that portion of the CBS game data that fell within the respective GRCA for each of the nine six-hour vignettes. After a period of familiarization and the completion of the first and second vignettes, the TTL scenario team lead left the conversion to the Janus programmers. The TTL continued to provide support to the Janus programmers by telephone.

C2.5 Prepare JIM Data for Test Support

The JIM-produced intelligence message traffic was extracted and printed from the CBS game tape in the six-hour segments corresponding to the series of vignettes. The messages were sorted by time blocks and prepared for passing to the participating test unit intelligence cell. The message traffic would be used to track red forces in the best resolution possible and would be combined with test Joint STARS sensor data to formulate target nominations.

C2.6 Facilitate Test Intelligence Traffic Flow

The intelligence message traffic was passed to the test participants at the predetermined times. The facilitators also helped deconflict the CBS aggregate location data with the Janus entity-based location data. The deconflicted data were used to improve the realistic response to artillery action against Janus depicted targets.

C3.0 Scenario Development Process Improvement Recommendations

C3.1 Lessons Learned

The JADS scenario and scenario support materials were developed from the best information from the beginning to the end of the project. The experiences gained yielded several key lessons learned.

- The order of the scenario development and support process is important. Much of the scenario development is a building block process. If any step is out of order, omitted or slighted, the final product can be seriously degraded. Efforts to go back and change may affect the work completed after the point of correction. A supporting example from the JADS test would be that the GRCAs were plotted after the scenario development process was well along. If the GRCAs and the associated Joint STARS aircraft flight paths had been set early in the scenario development process, the combat and combat support activity in CBS could have been deployed and maneuvered in the areas that could be observed by the Joint STARS sensors.

- The current conversion process from aggregate simulation to entity simulation can be done, but the process is lengthy and largely sequential. Adequate time and resources must be planned to support the data conversion.

- Early delineation of test and scenario development requirements helps the whole process efficiency. The scenario can be properly developed to support initially stated requirements. New or changed test requirements that surface after critical development points may not be fully serviced in the scenario development because of time and resource constraints.

- The planning timeline should allow for inevitable adjustments as the test develops.

C3.2 Revise Process Order

If all relevant scenario-related planning information could be gathered and resources identified before beginning the development process, the following adjusted order would be appropriate:

- Key on test objectives at the beginning of the scenario development process.

- Set supporting scenario objectives. Build to fully support test and allow for full examination of systems under test.

- Develop *The Road to War* to delineate desired scenario environment.

- Define sensor coverage area. Establish GRCA.

- Consider coverage area of sensors when CBS and Janus simulation boundaries are set.

- Prepare simulation support documents to manage CBS game play.

- Set the force hierarchy. Determine friendly forces to be deployed and assess the desired opposing force structure needed.

- Assign supporting units.

- Validate force structure.

- Prepare unit templates.

- Set unit start locations.

- Set unit strength percentages.

- Prepare red and blue operations orders.

- Construct synchronization matrix to coordinate scenario build.

  - Plan simulation to focus scenario activity for each set of vignette objectives.

  - Structure matrix to serve as a script during CBS scenario tape build.
- Train CBS workstation operators.
- Build CBS game tape.
- Set and monitor intelligence collection.
- Validate CBS tape.
- Prepare Vision XXI and game truth capture.
- Provide CBS data for conversion to Janus.
- Prepare to support test team during actual event.

C4.0 Assess Process Automation Potential

Within the resources and time allotted, an assessment was made to determine where automation could assist in developing a similar or larger scale simulation-based event. People who were experienced in the development and operations of CBS and Janus were consulted. Several others who are involved in the development and integration of future simulation support programs were interviewed. People in the military testing community and active military operations were also queried. The following observations were derived from that assessment.

C4.1 Observations

- The present tools used to develop a simulated environment combing current aggregate simulations (such as CBS) and entity simulations (such as Janus) are inadequate to support real-time interaction between the two types with any fidelity. These simulations were designed for specific purposes and were not intended to be interactive. The current process used for JADS resulted in fixed scenarios in Janus. This process does not allow for real-time interaction between a live CBS game and a live Janus game.
- The related developmental efforts are formative and incomplete at this time.
- There are no interface tools presently developed to successfully support real-time interaction of the subject systems.
- The Joint STARS aircraft platform and its associated sensors cannot be actively integrated into large-scale simulations such as those supporting integrated Automated Battle Control System tests or U.S. Army corps-level warfighters unless entity-level resolution of forces is depicted.

C4.2 Focus for Potential Automation Support

The scenario development process used in the JADS test focused on simultaneous use of CBS aggregate and Janus entity-based simulation systems. If the test and operations communities choose to further develop this type of fixed scenario or to develop a larger more interactive scenario support set to facilitate large-scale, free-play operations, automation must be incorporated into the process.

The need for automation should be considered in two categories.

- Automation support to the basic scenario development process used for the JADS End-to-End Test. This process resulted in fixed Janus scenario vignettes.

- Automation applied to work the CBS to Janus or aggregate-based simulation to entity-based simulation translation problem that would enable real-time interaction between CBS and Janus.

C4.2.1 Basic Scenario Automation Support

Several ad hoc automation tools were developed during the scenario development. The preparatory documentation and databases were developed within personal computer office tools. Much of the data manipulation after the CBS tape was built was done within the CBS VAX host computers. The Vision XXI tool described earlier was invaluable as analysts searched the prepared game for activity that would support the test best. Vision XXI was also used as an automated monitor tool during the actual test phases.

Though automation support was integral to the scenario development process, the human effort required to work through many of the steps the first time begs more automation support. Developing macros or other small programs to speed the development process can boost many of the scenario development steps. If the revised process order of paragraph C3.2 is followed, an event planner should apply automated support to as many of these steps as possible.

C4.2.2 Aggregate to Entity-Based Simulation Automation Support

The aggregate to entity translation developed for the JADS End-to-End Test consisted of converting pretaped CBS data to Janus format. Given adequate resources, programmers should be able to develop effective translator tools to use for this situation. Assuming the development of the tools, upgrades to the current two simulation support systems and any follow-on systems would have to be resolved with a common configuration management program. Without common configuration management, any translator development would quickly become out of date.

If an aggregate to entity translator that refined and translated precanned scenario data was successfully developed, the product from that translator would be limited in use. Possible uses might be checks or tests of isolated activities. Most large-scale system testing and operational training involves free-play and allows battle managers to maneuver force on force. The type of translator discussed so far may help with pre-event systems checks prior to a primary free-play event. However, that translator would not support dynamic free-play where movement and location data were not fixed for the whole scenario.

The larger problem set of developing translators between aggregate and entity-based simulation to support dynamic military operations is complex. The cost efficiency of such an endeavor would need to be analyzed in a separate study.

C5.0 Report Summary

The TTL and the attached contractor staff supported the JADS ETE Test by providing scenario preparation and support from concept stage through test execution. The process employed demonstrated what could be done to provide a large-scale, aggregate test environment and a limited focus at the entity level for fixed scenario periods or vignettes. The demonstration did not, however, answer requirements for large-scale depiction of entity level combat forces. The process the TTL used could be reduced in complexity and time required with the development of automation tools to use on various stages of the process. The larger issue of developing a large-scale, real-time dynamic interface between CBS and Janus remains an open issue. Further study to analyze the need and cost efficiency of such a large-scale, dynamic CBS to Janus interface should follow.

Appendix D – Janus Support for JADS Joint Test and Evaluation (JT&E)

D1.0 Simulation Support to JADS JT&E

D1.1 Constructive Simulation Selection Process

To generate the "notional corps" rear area, a constructive, entity-level simulation was required. These requirements were identified as evaluation criteria of the capability of various existing simulations to support the JADS End-to-End (ETE) Test:

- Capable of simulating or of being modified to simulate at least 5000 distinct entities with at least twenty-five percent moving in a reasonable and affordable manner
- Capable of issuing distributed interactive simulation (DIS) 2.0.4 entity state protocol data units (ESPDUs) that describe each entity simulated
- Capable of receiving and acting upon ESPDUs, fire protocol data units (PDUs), and detonation PDUs
- Capable of running for at least eight hours with human intervention as required
- Capable of running at or representing real-time actions
- Capable of using a terrain database at least 200 kilometers (km) by 200 km and based on National Imagery and Mapping Agency products
- Must have a verification and validation (V&V) history, an accreditation history for analysis, be under configuration control, and be well documented
- Capable of reasonably representing entity maneuvers, including stopping and turning
- Capable of representing the effects of a bombing or missile attack on the entities represented in an acceptable and credible manner

Table 1 summarizes the review of six candidate simulations. This analysis indicated that none of the constructive simulations evaluated would meet the ETE Test requirements without modification and/or further development. JADS selected the Janus simulation as the best candidate for upgrading to meet its requirements. Janus is under the configuration control of the U.S. Army Training and Doctrine Command (TRADOC) Analysis Command (TRAC), White Sands Missile Range (WSMR) and the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM). JADS entered into an agreement with TRAC-WSMR to modify Janus, as appropriate, to be able to represent at least 5000 entities. The capability for entity-level data generated by Janus to be converted into ESPDUs was made possible by TRAC-WSMR developing an interface for that purpose.

D1.2 ETE Test Phase 2

Phase 1 concluded with the successful definition and refinement of an advanced distributed simulation (ADS) synthetic environment. The intent of Phase 2 was to evaluate the utility of that ADS synthetic environment to support developmental test and evaluation and early operational test and evaluation of a command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) system in a laboratory environment.

Each test activity required the development of one or more scenarios designed to meet the test objectives. Scenarios designed for developmental testing (DT) are based on the system specifications of the test system and require careful analysis and testing to ensure the DT objectives are met. Scenarios developed for operational testing (OT), however, are based on a large-scale scenario and are focused more on operational realism than specification accuracy. JADS developed two scenarios for verification and validation, 12 scenarios for DT, and TRAC-WSMR developed five scenarios for OT. Note that OT scenarios were based on an expanded version (128 hours) of a U.S. Army Test and Experimentation Command (TEXCOM) scenario, *The Road to War*, that has been used to test components of the Army Tactical Command and Control System. JADS selected nine 6-hour vignettes from that scenario, five of which were implemented in Janus.

Table D-1. Comparison of Wargaming Constructive Simulations

	JANUS	EAGLE	CBS	Brigade Battalion Simulation	Joint Conflict Model	STAGE
Operating System	OpenVMS, HP-UX, Sun OS	Sun OS	OPS 5	OpenVMS	OpenVMS	Silicon Graphics IRIX
Application	training and combat development	combat development	training	training	training and doctrine development	demo
Number of Entities	1200 total upgradeable to 9999	division to corp-level unit representation	15,000 - 20,000 units brigade-level representation	brigade game plays brigades – using 20 MODSAFs ~ 2000	600x600	lots at a cost
DIS Compliant?	Sep-94	yes, through SAFOR	aggregate-level simulation protocol to DIS, date unknown	yes, through MODSAF	will be when combined with Janus	no
Cost to Make DIS	N/A	N/A	N/A	N/A	N/A	unknown
Battle Decision Intelligence	human-in-the-loop & expert system	expert system, combat orders, and SAFOR	None	MODSAF	human-in-the-loop & expert system	no - scripts
Real Time	event based but events run at real time	SAFOR	unknown	MODSAF	yes	yes, depending on processor
Minimal Computer Processing Unit	16 MB	48 MB	128 MB + 16 MB	Multiple (up to 10 Micro VAX's)	16 MB	depends on number of units - minimal, Iris
Terrain	DMA	DMA	HEX?	laser disk video displayed	DMA	?
Database	SWA	SWA	SWA	not SWA-several	SWA	limited SWA
Size	1000x1000cells resolution-dependent size upgradeable to 400x400km	corps	corps +	10,000sq km to 30,000sq km	100x100km upgradeable to 400x400km	?
Timing	can play real time	real time with caution, 5 minutes interactions	real time	real time	can play real time	can play real time
Interactive	yes	yes (SAFOR)	unknown - not at entity level	yes (MODSAF)	yes	by rewriting scripts
Kill Assessment	yes	yes	yes	yes	yes	yes
Data Flow Format	can mirror	can't mirror	can't mirror	can't mirror	can't mirror	can't mirror
Ownership	TRAC-WSMR/ STRICOM	TRAC	STRICOM	Combined Arms Center training	going to TRAC-WSMR	proprietary
V&V	yes - TRAC	no - in process	no - in process?	no - status unknown	no	no - none planned

DMA = Defense Mapping Agency   km = kilometer   MB = megabytes
MODSAF = modular semiautomated forces   SAFOR = semiautomated forces   sq = square
STRICOM = U.S. Army Simulation, Training and Instrumentation Command   SWA = Southwest Asia

At the conclusion of the Phase 2 DT, the OT which used the entire ETE Test synthetic environment to include constructive, virtual, and live participants began. Janus was used to provide constructive targets for the Joint Surveillance Target Attack Radar (Joint STARS) sensor being simulated by the Virtual Surveillance Target Attack Radar System (VSTARS). VSTARS radar reports were sent to the E-8C workstations in a Northrop Grumman laboratory and to a light ground station module (LGSM) located at Fort Hood using the surveillance control data link (SCDL) interface. The LGSM was in support of a subset of the tactical analysis cell (TAC) that merged Joint STARS data with other intelligence sources to analyze the battlefield and select candidate targets for the Army Tactical Missile System (ATACMS). The candidate targets were sent to the Depth and Simultaneous Attack Battle Lab (D&SA BL) at Fort Sill, Oklahoma, where they were analyzed and a doctrinally correct artillery command and control was simulated to determine if an ATACMS would be fired at one or more of the candidate targets. Messages describing the firing and detonation of the missile were sent back to Janus for assessment of damage. Data were also collected to support the evaluation of operational measures of effectiveness and to allow JADS to evaluate the utility of the environment to support operational testing.

D2.0 Enhancement of Janus Capabilities to Support the ETE Test

D2.1 Background

Janus is a constructive, interactive, computer-based simulation of combat operations conducted by platoons through brigades. The original Janus simulation began in the late 1970s at Lawrence Livermore National Laboratories to provide commanders with interactive control of a combat simulation in the presence of nuclear effects. In 1983, TRAC-WSMR obtained Janus and enhanced it as a high-resolution simulation to support analysis for Army combat development. In 1991, TRADOC selected Janus for training at the company and platoon levels. Janus has also been used by the Command and General Staff College to train new battalion and brigade commanders on the principles of synchronized combined arms operations.

Janus is a suite of programs made up of more than 200,000 lines of FORTRAN code. These programs produce an environment that allows the user to set up and execute a desired battle. Terrain, performance data, forces, unit symbols, and command and control overlays are typical entities that can be developed and edited to suit the user. Interactive graphics programs such as the Janus analyst workstation (JAAWS) and the controller workstation (CONWOR) add to the utility and versatility of the Janus application tools available to the user.

TRAC-WSMR has had an ongoing program of enhancement and improvement of Janus since the mid-1980s. JADS entered into an agreement with TRAC-WSMR (combined in some cases with other ongoing programs) to sponsor various enhancements to Janus to allow it to meet ETE Test requirements.

D2.2 Capability to Create, Deploy, and Maneuver Large Numbers of Entities

Janus v6.88D included enhancements to create, deploy, and maneuver large numbers of entities. The number of units allowed in Janus was extended from 1200 to 6000, then to 8000, and most recently to 9999 in Janus v6.88D. Initial tests of the first extension to 6000 units revealed that version would not run at real time because of the updating of the unit locations on the graphic display. To remedy this situation, several major creative changes were required, and the design was based on solid computer science theory. In order to reduce the graphic update time required, a process called heterogeneous aggregation (HA) was implemented. The interactor is able to dynamically select the level of detail of the units displayed on the graphic screen. A graphics interface that allows the user to build and modify a force according to military organizations with specification to the entity level possible at any level of aggregation was added to the FORCE editor. No phenomenology was changed for HA as the warfighting engine still operates at the entity level. Janus was modified to allow deployment and route building for organizations. The large numbers of units did require that some functions not directly related to HA be modified. Even more changes were made after observing users' struggle with building and executing large scenarios. Other model entity limits that have been increased (and their maximum value) in Janus v6.88D for a scenario are

1500	Number of indirect fire units
400	Number of system types
100	Number of indirect fire system types
300	Number of direct fire system types
400	Number of direct fire weapon types
24	Number of missions per indirect fire unit
60	Number of special radars
400	Number of actively searching radars at any one time
100	Number of special flyer units
100	Number of large area smoke clouds
500	Number of clouds
300	Number of ammo supply units
30	Number of ammo types for an ammo supply unit
100	Number of petroleum, oils and lubricants (POL) tankers
500	Number of obstacles
150	Number of nodes in a route
4000	Number of probability of hits/probability of kill (PH/PK) data sets

D2.3 Enhancements to the DIS Interface in Janus

Prior to the JADS project, TRAC-WSMR used an external program, Janus distributed interactive simulation (JanDIS), which ran on the same host and shared memory with Janus, the combat model program, to communicate with other systems on a network. Utilization of JanDIS by JADS and other distributed projects revealed that the arrangement was too difficult and cumbersome to use. The DIS interface was developed and integrated into Janus with a graphical interface for user control of runtime parameters. The PDUs resulting from firing and detonation events were implemented and tested in the JADS network in coordination with the Tactical Army Fire Support Model.

D2.4 Development of the Janus Plan View Display (JANPVD)

When Janus is used in a stand-alone exercise, the JAAWS program is used as an after-action review tool. When Janus is part of a distributed application, information from entities not under control of Janus would not be available to JAAWS. JANPVD was then developed (similar to the JAAWS pattern) to display PDUs from all sources. JANPVD can display information in real time or it can run from recorded data to provide replay capability. JANPVD displays unit positions, losses, direct fires, indirect fires, and artillery impacts. The user can select from six different graphs of analysis measures as a function of time. In the replay mode, the user has the additional capability to display unit movement and routes.

D2.5 Increased Speed of Line-of-Sight (LOS) Calculations

Previously, running large scenarios in Janus resulted in users having problems with run time. The line-of-sight (LOS) calculation in Janus is the major consumer of central processing unit (CPU) resources when executing large scenarios. Three software changes in this area were made to streamline the LOS process, thus reducing required CPU resources and run time.

An algorithm, generally referred to as "bilateral interpolation," was used to determine if the LOS ray between two points (in three dimensions) was intersected by the elevation of the terrain between the two points. While this algorithm is accurate (in a theoretical sense), it is not operationally efficient since three interpolations are required at each "calculation point" along the LOS ray. To remedy this, TRAC-WSMR developed and integrated a new algorithm called "'unilateral interpolation" for use in Janus. Except for the two endpoints, the new algorithm requires only one interpolation at each calculation point along the LOS ray. Calculation points are at intersections of the LOS ground-trace with "grid cell" boundaries. Some overhead is required to determine parameters that enable the fast calculation of grid cell boundary intersections. However, only one interpolation is required per calculation point in that case. In stand-alone test programs using representative-length LOS calculations, the new algorithm appeared to be about twice as fast as the old algorithm.

A low-level LOS driver routine (subroutine DOLOS) performs LOS determination for both terrain elevation and feature data. DOLOS divides a LOS ray into several segments, then considers each segment one-at-a-time to determine if either elevation or feature data would interfere with LOS for that segment. A TRAC LOS study showed that it is generally faster (particularly if the terrain file contains a significant number of terrain features) to not divide the LOS ray into segments, but rather, first determine if elevation data interferes with LOS (using the entire length of the LOS ray), and if so, skip the feature calculations. In a sense, the elevation calculation serves as a "filter" for the feature calculation. The speed up in Janus because of this change was very difficult to quantify because it was so extremely terrain and scenario dependent. Suffice it to say, the change resulted in a significant speed up for most "typical" Janus scenarios.

The Janus Terrain Editor (TED) determines what types of terrain features, if any, are "close" to each terrain "grid cell" and stores that information in the terrain file. Janus uses this information to determine what type(s) of features to check when determining if a particular LOS ray intersects any terrain features. The LOS study showed that the calculations to determine possible intersection of features with the LOS ray are performed much faster in Janus if the features are sorted by type so that all features of a given type are stored contiguously in memory. Therefore, TED has been modified to sort the terrain features by type when the terrain file is saved. In addition, Janus has been modified to take advantage of this fact whenever calculations involving all features of a given type are required. Testing indicated that a significant speed up for Janus is obtained even when running with terrain files with relatively small numbers of terrain features (500 to 1000).

D3.0 Janus Utility Issues

D3.1 Janus Scenario Development and Preparation

The Janus scenario preparation process was quite involved and composed of several steps. Two output files from the corps battle simulation (CBS) for the corps scenario were provided to TRAC-WSMR. The area covered for the corps scenario was a 500 km X 500 km box. The next step was to develop a Janus map file that would contain only the units that the Joint STARS/VSTARS would be observing over the corps area (the ground reference coverage area or GRCA). Units within the GRCA were identified from one of the CBS files as were the number and types of systems within each unit. If the number of units ever exceeded 9999, the units were ranked giving targets that moved during the scenario priority (i.e., if targets had to be ignored because of the 9999 unit limit, they would be stationary targets). The position location data of the units were provided on another file that had to be pared down to reflect the units selected in the first step. This task was facilitated by converting the file into an Excel© document and sorting it accordingly to identify what units to omit. This completed the task of identifying the organization and maneuver of the units for the Janus scenarios. The force was deployed in Janus and routes for the moving entities were provided according to the scenario and in consonance with the threat operations plan.

D3.2 Verification of Artillery Damage Assessment in Janus

As mention previously, the information from the various intelligence sources represented was analyzed and candidate targets were selected for the ATACMS. The candidate targets were sent to the D&SA BL where it was determined if an ATACMS would be fired at one or more of the candidate targets. Information describing the missile firings was then sent back to Janus for assessment of the damage. The D&SA BL noted that the resulting damage assessment for the ATACMS from Janus appeared to be lower than what they thought it should be. The Janus algorithms for ATACMS representation and damage assessment, together with supporting data, were extensively reviewed and checked out to ensure conformity with joint munitions effectiveness manual (JMEM) methodology and Army material systems analysis activity (AMSAA) data.

D4.0 Conclusions

The enhancements made to Janus to meet the JADS requirements are of broad general use to all Janus users and have resulted in a tremendous benefit to the U.S. Army. Of the many benefits of the JADS project, the addition of these capabilities to the Janus model has certainly been significant.

Appendix E – ETE Test Program Work Breakdown Structure

E1.0 Background

JADS personnel worked with the MITRE Corporation to produce an advanced distributed simulation (ADS) cost model guidance (CMG) document. To develop the CMG, MITRE created a work breakdown structure (WBS) relative to ADS-based testing. (For the latest version of the ADS WBS, please contact the JADS Joint Test Force.) Section 3 identifies the program costs for the End-to-End (ETE) Test, as applied against the most recent version of the ADS WBS.

E2.0 WBS Terms and Definitions

The following terms and definitions were used in the ETE Test WBS.

1.X **System Test and Evaluation** (T&E). This element refers to the use of prototype, production, or specifically fabricated hardware and software to obtain or validate engineering data on the performance of the prime mission equipment (PME). This element includes the detailed planning, execution, support, data reduction, and reports from such testing (exclusive of those required under data), and all hardware items which are consumed or planned to be consumed in the conduct of such testing. It includes all effort associated with the design and production of models, specimens, fixtures, and instrumentation in support of the system-level test program. It also includes all planning, management, and coordination of federation developers required to incorporate ADS use into traditional T&E methods.

1.X.0 **Feasibility Analysis.** This element provides the decision maker (usually a program manager) with the necessary information based on quantitative and qualitative analyses on which a decision can be made to use or not use ADS in the program's T&E phase. Also, if ADS will be used, this analysis should support identification of how it can best be used to supplement traditional T&E capabilities and what resources may be available and their location.

1.X.0.1 **Test Planning Methodology.** An approach to analyzing applicability of ADS in meeting a program's test objectives. Included in this approach are a survey of availability of models and simulations, networks, facilities, trained personnel, etc., to support a program's T&E requirements. Also, this analysis addresses the program's required security and the ability and availability of equipment and personnel who can sustain the program's security integrity.

1.X.0.2 **Rough Order of Magnitude (ROM) Cost Analysis.** Perform a ROM cost estimate analyzing cost of applying ADS. Costs related to development, modification, and /or procurement of modeling and simulation (M&S), software, hardware, networks, facilities, personnel, training, validation, verification and accreditation (VV&A), and documentation are some examples of elements that should be included in the estimate.

1.X.0.3 **Risk Analysis.** Perform an initial analysis of technical and programmatic risks of incorporating or not incorporating ADS methods into the traditional T&E approach.

If program management has reached a decision to incorporate ADS into the T&E phase, some WBS elements will need to be modified, while others will have to be added. The following WBS elements include tasks required to incorporate ADS into a program's developmental test and evaluation (DT&E) phase. These WBS elements are not stand-alone products and are not representative of all activities necessary for a successful T&E phase.

1.X.1 **Development Test And Evaluation** (DT&E). Test and evaluation is conducted on systems to (a) demonstrate that the engineering design and development process is complete, (b) demonstrate that the design risks have been minimized, (c) demonstrate that the systems will meet specifications, (d) estimate the system's military utility when introduced, (e) determine whether the engineering design is supportable (practicable, maintainable, and safe) for operational use, (f) provide test data with which to examine and evaluate trade-offs against specification requirements, life cycle cost, and schedule, and (g) perform the logistics testing efforts to evaluate the achievement of supportability goals, and the adequacy of the support package for the system, e.g., deliverable maintenance tools, test equipment, technical publications, maintenance instructions, and personnel skills and training requirements, etc. DT&E is planned, conducted and monitored by the developing agency of the Department of Defense (DoD) component.

DT&E tasks are the planning, conducting, and reporting of tests. Planning tasks include selecting the tools such as the facilities, equipment, personnel, software, etc., needed to conduct the tests, determining the sequence of tests to be performed, writing detailed test procedures for individual tests, and determining the expected test outputs. Also, before the tests are conducted, the necessary hardware and software integration are done. Then the tests are conducted. Test environments progress from least stressful to the most stressful. The test program encompasses system integration and performance tests as well as reliability, maintainability, and environmental tests. The PME, to a large degree, determines specific DT&E tests. After the tests are conducted, the collected data are reduced and analyzed. Data reduction is the filtering and statistical assessment of the raw data for specific characteristics and information. The result of the test analysis is the test report.

1.X.1.1 **Planning.** The purpose of this section is to initiate the studies and analyses of ADS requirements, architecture, resources, and constraints, define objectives, and identify critical systems. As part of the planning effort, organizations that will be used in the simulation federation should be contacted and talks initiated toward achieving the required agreements on responsibilities and schedules. Note that several of these activities will continue definitional work started in 1.X.0.1.

1.X.1.1.1 **ADS Requirements Definition**. Define ADS test objectives, measures of effectiveness and performance, needed resources, and constraints. Initiate development of plans and procedures for directing architecture and test toward meeting objectives.

1.X.1.1.1.1 **Requirements Identification.** Develop an initial problem statement from information available at this stage of development.

1.X.1.1.1.1.1 **Critical Systems of Interest Description.** Develop a clear and unambiguous statement of program needs to include a high-level description of critical systems of interest, required fidelity and resolution of simulated entities, and output data requirements.

1.X.1.1.1.1.2 **Support Resources Availability.** Identify the resources that will be available to support the ADS architecture (funding, personnel, tools, facilities, etc.).

1.X.1.1.1.1.3 **Programmatic Risk Identification.** Determine known constraints that could affect the ADS architecture development, e.g., due dates, security requirements, etc.

1.X.1.1.1.2 **Objectives Development.** Refine the statement of program needs into a more detailed set of specific objectives and plans for the ADS architecture.

1.X.1.1.1.2.1 **Test Objectives, Scenarios, Conditions and Measures Identification.** Develop a prioritized list of measurable objectives for the ADS architecture. Assess availability of government or contractor furnished equipment, facilities and data. Define operational context constraints or preferences including geographical regions, environmental conditions, threats and tactics.

1.X.1.1.1.2.2 **Plan Development.** Develop the ADS architecture and network implementation plans showing planned schedule and major milestones. Develop the ADS configuration management plan, data collection test plan, and initial verification, validation and accreditation (VV&A) test plan.

1.X.1.1.1.2.3 **Security Requirements Identification**. Identify security position including expected security level and possible designated approval authority.

1.X.1.1.1.2.4 **Support Tools Selection.** Identify and select tools to support scenario development, concept analysis, configuration management, VV&A and test activities. Tool selection should be based on tool availability, cost, maintainability, applicability to the given function, and the ability of a given set of tools to exchange data within the ADS architecture.

1.X.1.1.2 **Establish Federate Development Team.** Designate members of federating system's organizations to coordinate development of ADS environment including the architecture, federation object model (FOM), schedules, and other test requirements. Define requirements, expectations, test objectives, etc., to provide these organizations with an understanding of what resources are expected from them in personnel, training, equipment, and what costs they may be required to bear.

1.X.1.1.3 **Reporting And Documentation.** Document and/or report on all plans and procedures required achieving the objectives of the elements associated with 1.X.1 to include all technical, management, programmatic reports, plans, briefings, engineering drawings, etc.

1.X.1.2 **Concept Development.** The purpose of this section is to develop a representation of the real-world domain of interest (entities and tasks) in terms of a set of required objects and interactions.

1.X.1.2.1 **Scenario Development.** Develop a functional specification of the ADS test scenario, using the operational context constraints identified in 1.X.1.1.1.2.

1.X.1.2.1.1 **Entities Identification.** Identify all entities that must be represented in simulations or otherwise by the ADS architecture.

1.X.1.2.1.2 **Functional Description of Entities.** Document functional descriptions of the capabilities, behavior, and relationships among entities over time.

1.X.1.2.1.3 **Relevant Environmental Conditions.** Identify relevant environmental conditions that impact or are impacted by entities in the ADS architecture including initial and terminal conditions (e.g., textual scenario descriptions, event-trace diagrams, and graphical illustrations of force laydowns and communication paths).

1X.1.2.1.4 **Conceptual Model Development.** Select technique for developing the conceptual model (e.g., static process flow diagram, process flow diagrams, correlation tables of objects and activities, descriptive texts) and initiate development to capture all features of the test environment.

1.X.1.2.2 **Concept Analysis.** Develop an implementation-independent representation of ADS architecture.

1.X.1.2.2.1 **Entity Characteristics, Relationships and Interactions Evaluation.** Identify all entity characteristics and the static and dynamic relationships among them. Identify behavioral and transformational (algorithmic) aspects of each using the ADS architecture scenario.

1.X.1.2.2.2 **Entities Representation.** Determine entity characteristics (attributes) and interaction descriptors (parameters).

1.X.1.2.2.3 **ADS Architecture Requirements Determination.** Determine ADS architecture requirements such as data, latency, synchronization, network, interface, test control and monitoring.

1.X.1.2.3 **Reporting And Documentation.** Develop all plans, procedures, reports and documentation required to meet the objectives of the elements associated with 1.X.1.2.

1.X.1.3 **Design And Development.** The purpose of this section is to do detailed design of the test environment to meet the test objectives and ensure adequate data collection; procure the hardware and software, and finalize schedules for installation, integration, VV&A, and test execution.

1.X.1.3.1 **ADS Architecture Design.** Design the ADS architecture that will be required to test and evaluate the system.

1.X.1.3.1.1 **ADS Architecture Detailed Design.** Design a systems engineering methodology to support ADS architecture development and integration. This requires close coordination among all facilities and entity participants to ensure a common understanding of the ADS architecture goals and requirements.

1.X.1.3.1.1.1 **Node Site Surveys.** Select ADS nodes and survey each location. Node selection is based on fidelity, availability, cost and schedule. Site surveys determine facility communications architecture and requirements and space requirements for tester-supplied equipment and personnel.

1.X.1.3.1.1.2 **Test Control And Analysis Center (TCAC) Definition.** Define required TCAC capabilities and optimal location.

1.X.1.3.1.1.3 **Security Approach Development.** Perform security risk assessment and develop a security concept of operations.

1.X.1.3.1.1.4 **ADS WAN Requirements Definition**. Define ADS Wide Area Network (WAN) requirements (bandwidth, data rate, acceptable latency, network management/control responsibility).

1.X.1.3.1.1.5 **ADS Network Components Determination.** Determine if DoD-sponsored networks meet the ADS WAN requirements or if commercial resources are required. If DoD-sponsored common-user services are not viable, application for waiver from the Defense Information Systems Agency (DISA) and contract for leased lines would be required.

1.X.1.3.1.1.6 **ADS Network Hardware Selection.** Select hardware for the ADS network (routers, channel service units, data service units, multiplexers, encryptors).

1.X.1.3.1.1.7 **Test Control Hardware and Software Selection**. Select test control hardware and software based on the data and voice communications requirements and TCAC space requirements and layout.

1.X.1.3.1.1.8 **Data Collection and Instrumentation Requirements Determination.** Select instrumentation types and data logging software based on data requirements. Determine hardware requirements for data storage and handling (tape drivers, compact disks, optical disks). Develop handling procedures for collecting and storing data from the distributed network.

1.X.1.3.1.1.9 **Time Synchronization Method Determination**. Determine method for synchronizing time stamps for data loggers. Select synchronization hardware and software.

1.X.1.3.1.1.10 **ADS Architecture Development And Integration Plan.** Complete final version of formalized plan for ADS architecture development and integration.

1.X.1.3.2 **ADS Architecture Development.** Initiate procurement and/or development of tools and identification of other procedures to build the ADS architecture.

1.X.1.3.2.1 **ADS Network Procurement.** Procure or develop ADS-specific hardware tools for network analysis and monitoring.

1.X.1.3.2.2 **Secure/Encrypted Operations Procedure Development and Approval.** Develop secure/encrypted operations procedures for approval by the designated approval authority (DAA). Achieve formal security accreditation for all network and facilities.

1.X.1.3.2.3 **Hardware/Software Configuration Control Implementation.** Implement strict hardware/software configuration control.

1.X.1.3.2.4 **Data Protocols Development.** Develop standard data protocols to satisfy ADS architecture communications and interoperability requirements.

1.X.1.3.2.5 **Interface Design, Build, or Procurement.** Design, build, or procure simulation and network interfaces, runtime infrastructure (RTI) interfaces (if required), and special purpose interfaces.

1.X.1.3.2.6 **Simulation Modifications.** Identify and implement modifications necessary to use external inputs and to generate required outputs from existing simulations.

1.X.1.3.2.7 **Range Data Processing Modifications**. Identify and implement modifications necessary to meet time-space-position-information accuracy, smoothness, and latency requirements.

1.X.1.3.2.8 **Facilities Modifications.** Identify and implement modifications required for replay capability to be used during integration testing.

1.X.1.3.3 **Reporting and Documentation.** This element includes ADS-specific data. This element includes, for example, all plans, procedures, reports and documentation required to meet the objectives of the elements associated with 1.X.1.3.

1.X.1.4 **Installation, Integration and Test.** The purpose of this section is to install and integrate the ADS hardware and software subcomponents and to conduct testing to ensure that the ADS architecture meets interoperability requirements.

1.X.1.4.1 **Execution Planning.** Define requirements to support execution of the ADS architecture.

1.X.1.4.1.1 **Integration Test Plan.** Develop integration test plan to support incremental checks on configuration during ADS architecture build-up.

1.X.1.4.1.2 **Test Control Procedures.** Develop test control procedures for ADS architecture integration and test.

1.X.1.4.1.3 **Detailed Test Execution Plan.** Develop detailed test execution plan for ADS architecture integration and test.

1.X.1.4.1.4 **Security Test and Evaluation Plan.** Develop security test and evaluation plan that defines procedures for testing and evaluating network security.

1.X.1.4.2 **ADS Architecture Integration and Test Execution.** Integrate all participating facilities and entities into one operating environment and verify that all components are interoperable to the degree required to achieve the ADS architecture objectives.

1.X.1.4.2. **Hardware/Software Installation.** Install and check out network hardware and software.

1.X.1.4.2.2 **Compliance Testing.** Perform individual compliance testing for each facility and node to verify correct implementation of ADS architecture requirements.

1.X.1.4.2.3 **Integration Testing.** Perform incremental integration testing, using iterative "test-fix-test" approach including replay of trials to diagnose problems and verify fixes. This includes a) check-out of interfaces and facility modifications with linking between pairs of nodes, b) baseline performance of network with no loading from the simulations or entities, c) test performance of critical portions of network under loading representative of test conditions.

1.X.1.4.2.4 **Risk Reduction Missions.** Execute scenarios with fully linked test execution configuration. Include security certification (if required) and evaluation of test control and monitoring procedures as well as data collection and analysis procedures.

1.X.1.4.3 **Verification, Validation and Accreditation (VV&A).** Obtain VV&A of the ADS architecture. Consider VV&A policies and procedures for each individual entity as well as system compliance, compatibility and interoperability requirements for the ADS architecture.

1.X.1.4.3.1 **ADS Verification.** Verify that the ADS architecture accurately represents the developer's concept description and specifications and meets the needs stated in the requirements document.

1.X.1.4.3.1.1 **Distributed Network Verification.** Verify that the distributed network meets the ADS architecture requirements.

1.X.1.4.3.1.2 **Integration Testing.** Test to determine that the integrated environment operates as required and meets specifications.

1.X.1.4.3.2 **ADS Validation.** Determine the extent to which the ADS architecture represents the real world from the perspective of its intended use, i.e., it meets requirements of test objectives.

1.X.1.4.3.2.1 **Test Environment Validation.** Validate the test environment to the VV&A plan specifications.

1.X.1.4.3.2.2 **Comparison Standard Validation.** Validate the ADS architecture's performance against the comparison standard.

1.X.1.4.3.3 **Accreditation.** Obtain an official determination (based on experience and expert judgement) that the ADS architecture is acceptable for its intended purpose.

1.X.1.4.3.3.1 **Network Accreditation Requirements.** Define the network accreditation requirements.

1.X.1.4.3.3.2 **Synthetic Environment**

1.X.1.4.4 **Reporting and Documentation.** This element includes ADS-specific data. This element includes, for example, all plans, procedures, reports and documentation required to meet the objectives of the elements associated with 1.X.1.4.

1.X.1.5 **Test Execution and Analysis.** The purpose of this section is to conduct the tests, collect data, analyze test results, and provide feedback to the program manager and developer.

1.X.1.5.1 **Test Readiness Review.** Conduct a review to assess ADS architecture readiness for formal testing.

1.X.1.5.2 **Test Execution.** Exercise all components of the ADS architecture as an integrated whole to achieve the test objectives.

1.X.1.5.2.1 **Data Collection.** Collect data in accordance with approved data collection procedures.

1.X.1.5.3 **Results and Feedback.** Analyze test execution data and provide report to the program manager and developer.

1.X.1.5.3.1 **Data Analysis.** Analyze outputs from the test execution phase.

1.X.1.5.3.2 **Test Evaluation.** Evaluate results from the execution phase to determine if all test objectives have been met. If all objectives were not met, identify corrective actions to implement for retest.

1.X.1.5.3.3 **Provide Test Report.** Deliver test report and legacy products to customer and data repository.

1.X.2 **Operational Test And Evaluation (OT&E).** This element addresses test and evaluation conducted by agencies other than the developing command to assess the prospective system's military utility, operational effectiveness, operational suitability, logistics supportability (including compatibility, interoperability, reliability, maintainability, and logistics requirements), cost of ownership, and need for any modifications. The initial operational testing and evaluation (IOT&E) conducted during the development of a weapon system is included in this element. This element encompasses such tests as integrated system tests, flight tests and sea trials, mobility demonstrations, on-orbit tests, spin demonstrations, stability tests, etc., and support thereto, required to prove the operational capability of the deliverable system. Contractor support (e.g., technical assistance, maintenance, and labor material, etc.) consumed during this phase of testing is also included in this element.

If ADS was used during T&E, the ADS architecture can be reused. If modifications are required, some of the planning and preparation elements must be revisited prior to executing the test. If ADS was not used for developmental test and evaluation (DT&E), all elements from 1.X.1.1 through 1.X.1.5.3.3 must be incorporated into the OT&E process.

E3.0 ETE Test Work Breakdown Structure (WBS)

ETE Test Overall Observations:

Ideally, the WBS data collection process should be in place at the start of the ADS test. This process will include the development and maintenance of a dictionary of WBS terms and the creation of a manual describing the proper application of the WBS terms to ADS test activities. In addition, the process requires a point of contact for questions with respect to implementing the process accessible by ADS test members throughout the life of the ADS test.

Valid WBS data must be collected from all contractors and government organizations supporting the ADS test. The contractors and their subcontractors can be tasked to provide WBS data through contract deliverables. The government organizations can be asked to provide WBS data via specific provisions in memoranda of agreements between the ADS test team and the government organizations.

1.X System Test and Evaluation

1.X.0 Feasibility Analysis

During 1993-1994, a joint feasibility study (JFS) was conducted to determine the necessity and feasibility of a joint test and evaluation (JT&E) of distributed interactive simulation. This study defined the JADS System Integration Test, End-To-End Test, and Electronic Warfare Test.

The JFS took 13 months and cost $523,000: $460,500 for contractor support while $62,500 was for government travel. Each service provided additional funding for travel. The Air Force Operational Test and Evaluation Center (AFOTEC) funded and provided day-to-day operating costs, office equipment, and work areas. The JADS JFS team included 24 government and contractor personnel.

"JADS JT&E Joint Advanced Distributed Simulation Joint Feasibility Study Final Report." February 1995.

ETE Test Observation:

The future success of an ADS test is very much dependent on the level of rigor associated with a preliminary feasibility analysis. Having the right personnel with the necessary backgrounds and being able to do the necessary research, the JADS JFS was able to thoroughly and accurately define the ETE Test in terms of projected schedule, cost, and manpower requirements. Since these initial forecasts were realistic, the ensuing ETE Test could be successfully completed without any disruptions because of funding or personnel shortages or lack of time. In addition, during the course of the test, the ETE Test management could concentrate on technical and programmatic issues and not devote their energies to solving significant financial, personnel, or scheduling problems.

1.X.1 Development Test and Evaluation (DT&E). No WBS data available.

Northrop Grumman is currently developing an annual release of the radar software that will incorporate a revised version of the A-tracker software. This provided JADS with the opportunity to ask Northrop Grumman to conduct an ad hoc study, parallel to the normal testing of the A-tracker software, to determine if it would be possible to use the Virtual Surveillance Target Attack Radar System (VSTARS) to test this software.

Numerous problems were experienced because of the ad hoc nature of the study, both in the areas of software integration and scenario generation. Additionally, the verification and validation of VSTARS had not yet been completed and thus no results could be used as documentation for the annual release. Despite these problems, several lessons learned resulted from this study.

1.X.2. Operational Test and Evaluation (OT&E)

NOTES:
1. OT&E encompasses Phases 1-4 of the ETE Test.
2. ETE Test team expenses during Phases 1-4 were as follows:

	Phase 1	Phase 2	Phase 3	Phase 4
Hardware and Software Purchases	$21,040	$26,719	$ 925	$ 0
Travel	$85,530	$69,700	$39,650	$8,900
Training	$ 7,790	$ 3,889	$ 0	$ 0
Shipping	$ 0	$ 2,578	$ 82	$ 0

ETE Test Observations:

Test team travel costs may be significant during all phases of an ADS test.

Allocate funds in the early stages of an ADS test for test team training.

1.X.2.1. Planning

1.X.2.1.1 ADS Requirements Identification

Appendix I (Program Test Design) of the *JADS Joint Feasibility Study (February 1995)* provided the initial identification of ADS requirements with respect to the End-To-End Test. According to Figure 1-1, "JADS JFS Schedule," of the *JADS Joint Feasibility Study*, the program test design took about six months to develop.

The JADS *Joint Test and Evaluation Program Test Plan (February 1996)* provided a more detailed discussion of ADS requirements with respect to the End-To-End Test.

1.X.2.1.2 Establish Federate Development Team. Not applicable to ETE Test.

1.X.2.2. Concept Development

1.X.2.2.1 Scenario Development

Janus 6.88D development $852,000

ETE Test Observation:

Contracted scenario development can be expensive. In the case of the End-To-End Test, scenario development costs were about 11% of total test costs.

1.X.2.2.2 Concept Analysis

The JADS *Joint Test and Evaluation Program Test Plan (February 1996)* provided a discussion of concept analysis with respect to the End-To-End Test.

1.X.2.3 Design and Development

1.X.2.3.1 ADS Architecture Design

1.X.2.3.1.1.1 Node Site Surveys.. 1 day/node

1.X.2.3.2 ADS Architecture Development

1.X.2.3.2.1 ADS Network Procurement

Network equipment and instrumentation $173,720
Network leases (Phases 1-4) $379,488
Joint Surveillance Target Attack Radar (STARS) Joint Task Force $301,476
Fort Hood (Test and Experimentation Command) node $239,465
Fort Sill node $101,091

ETE Test Observations:

The sophisticated networking equipment and instrumentation required for an ADS test can be expensive.

ADS testers need to budget for recurring costs (i.e., network lease payments) as well as initial costs.

The support provided by other facilities to an ADS test can also be expensive.

1.X.2.3.2.5 Interface Design, Build, or Procurement

Surveillance control data link (SCDL) development $327,497

1.X.2.3.2.6 Simulation Modifications

VSTARS development (including contracting fee) $4,372,413
Advanced Radar Imaging Emulation System (ARIES)
development (including contracting fee) $901,474

ETE Test Observation:

Contracted simulation development and modification can be expensive.

1.X.2.3.3 Reporting and Documentation

Phase 1 ETE Test report .... 7 months

1.X.2.4 Installation, Integration, and Test

1.X.2.4.1 Execution Planning

1.X.2.4.1.2 Test Control Procedures .... 1 month

1.X.2.4.1.3 Detailed Test Execution Plan

Phase 1 test activity plan development, revision, and coordination .... 8 months
Phase 2 test activity plan development, revision, and coordination
(2 individuals worked full time) .... 4 months
Phase 3 test activity plan development, revision, and coordination
(2 individuals worked full time) .... 3 months
Phase 4 test activity plan development, revision, and coordination
(1 individual worked full time) .... 2 months

ETE Test Observation:

As an ADS test moves through its various phases, test team personnel will become more proficient at writing the necessary test execution plans, resulting in successively lower test plan production costs.

1.X.2.4.2 ADS Architecture Integration and Test Execution

1.X.2.4.2.1 Hardware/Software Installation .... about 1 week/node

1.X.2.4.2.3 Integration Testing

Phase 2 ETE Test: functionality and integration tests #1-4 .... 19 days
Phase 3 ETE Test: 25-26 Feb 99 and 10-12 Mar 99 testing .... 5 days

1.X.2.4.2.4 Risk Reduction Missions

Phase 2 ETE Test: pretest data reduction and analysis rehearsals .... 60 hours
Phase 2 ETE Test: risk reduction tests .... 5 days
Phase 4 ETE Test: 15-17 Mar, 24 Mar, and 29-30 Mar 99 testing .... 6 days

ETE Test Observation:

The costs of risk reduction testing are outweighed by their effect of improving the probability of success of the actual ADS testing.

1.X.2.4.3 Validation, Verification, and Accreditation (VV&A)

1.X.1.4.3.1 ADS Verification

1.X.1.4.3.2 ADS Validation

Prepare, coordinate, and revise *Verification and Validation Plan for the End-to-End (ETE) Test* (Appendix C to Version 2.0 of the *JADS Joint Test Force End-To-End Test Activity Plan,* September 1998 (1 individual assigned to this task) .... 1 month

Prepare, coordinate, and revise Phase 2 verification and validation results for the End-To-End Test (1 individual assigned to this task) .... 1 month

Phase 3 ETE Test: 13 Mar 99 testing .... 1 day

1.X.1.4.3.3 Accreditation

Prepare and convene accreditation board on 3 Feb 98 .... 2 days

Prepare and convene accreditation board on 1 Sep 98 .... 2 days

Prepare and convene accreditation board on 17 Feb 99 .... 2 days

Prepare for accreditation board planned for Jun 99 .... 1 day

1.X.2.4.4 Reporting and Documentation

Phase 1 ETE Test report development, revision, and coordination .... 7 months

1.X.2.5 Test Execution and Analysis

NOTES:
1. Phase 2 test: encompasses 14 Sep 98 - 6 Oct 98 testing
2. Phase 3 test: encompasses 13 Mar 99 testing
3. Phase 4 test: encompasses 19 Mar, 25 Mar, and 31 Mar 99 testing

1.X.2.5.1 Test Readiness Review

During ETE Test Phases 1-4: At least nine test readiness reviews and four integrated product team meetings .... 21 meeting days

ETE Test Observation:

The costs of test readiness reviews and integrated product team meetings are outweighed by their effect of improving communication within the ADS test team, therefore increasing the probability of success of actual ADS testing.

1.X.2.5.2 Test Execution

1.X.2.5.2.1 Data Collection .... about 1 hour/test trial

ETE Test Observation:

An ADS test can enjoy greatly reduced labor costs associated with the data collection process.

1.X.2.5.3 Results and Feedback

1.X.2.5.3.1 Data Analysis .... about 8-10 hours/test trial

1.X.2.5.3.2 Test Evaluation .... about 1-2 hours/test trial

ETE Test Observation:

Daily after-action conferences, at the end of each test trial, are useful, cost-effective forums for comparing ADS test results with test objectives.

1.X.2.5.3.3 Provide Test Report

Phase 2 ETE Test report development, revision, and coordination
(1 individual worked full time) .... 5 months
Phase 3 ETE Test report development, revision, and coordination
(1 individual worked full time) .... 3 months
Phase 4 ETE Test report development, revision, and coordination
(1 individual worked full time) .... 4 months

ETE Test Observation:

As an ADS test moves through its various phases, test team personnel will become more proficient at writing the required test reports, resulting in successively lower test report production costs.

Appendix F – Glossary

A

Accreditation. See: distributed simulation accreditation, model/simulation accreditation.

Accuracy. The degree of exactness of a model or simulation relative to an established standard with high accuracy implying low error. [DIS]

Activity. An event that consumes time and resources and whose performance is necessary for a system to move from one event to the next. [DIS]

Advanced Distributed Simulation (ADS). A set of disparate models or simulations operating in a common synthetic environment. The ADS may be composed of three modes of simulation: live, virtual and constructive, where the latter can be seamlessly integrated within a single exercise. **See also:** live simulation; virtual simulation; constructive simulation. [DIS]

Aggregate. An activity that combines individual entities into a singular entity. **Contrast with:** disaggregate. [DIS]

B

Battlespace. The three-dimensional battlefield. [DIS]

Benchmark. (v) The activity of comparing the results of a model or simulation with an accepted representation of the process being modeled. (n) The accepted representation of the modeled process. [DIS]

Bit. The smallest unit of information in the binary system of notation. [IEEE 1278.1]

Broadcast. A transmission mode in which a single message is sent to all network destinations, i.e., one-to-all. Broadcast is a special case of multicast. **Contrast with:** multicast; unicast. [IEEE 1278.2]

C

Compatible. Two or more simulations are distributed interactive simulation (DIS) compatible if (1) they are DIS compliant, and (2) their models and data that send and interpret protocol data units (PDUs) support the realization of a common operational environment among the systems (coherent in time and space). **Contrast with:** compliant, interoperable. [DIS]

Compliant. A simulation is distributed interactive simulation (DIS) compliant if it can send or receive protocol data units (PDUs) in accordance with Institute of Electrical and Electronics Engineers (IEEE) Standard 1278 and 1278 (working drafts). A specific statement must be made regarding the qualifications of each PDU. **Contrast with:** compatible, interoperable. [DIS]

Conceptual Model. A description of the content and internal representations which are the user's and developer's combined concepts of the exercise. It includes logic and algorithms and explicitly recognizes assumptions and limitations. [DIS]

Constructive Simulation. Models and simulations that involve simulated people operating simulated systems. **See Also:** war games; higher order model (HOM). [DIS]

Continuous Model. (l) A mathematical or computational model whose output variables change in a continuous manner; that is, in changing from one value to another, a variable can take on all intermediate values. For example, a model depicting the rate of air flow over an airplane wing. **Syn:** continuous-variable model. (2) A model of a system that behaves in a continuous manner. **Contrast with:** discrete model. [DIS]

Continuous Simulation. A simulation that uses a continuous model. [DIS]

Continuous-Variable Model. **See:** continuous model. [DIS]

Control Station. (1) A facility which provides the individual responsible for controlling the simulation and the capability to implement simulation control as protocol data units (PDUs) on the distributed interactive simulation (DIS) network.
Syn: simulation - management station. [DIS]

D

Data. Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation or processing by humans or automatic means. [DIS]

Database. A collection of data organized according to a schema to serve one or more applications. [DIS]

Data Certification. The determination that data have been verified and validated. (1) Data producer certification is the determination by the data producer that data have been verified and validated against documented standards of criteria. (2) Data user certification is the determination by the application sponsor or designated agent that data have been verified and validated as appropriate for the specific modeling and simulation (M&S) usage. [DIS]

Data Logger. A device that accepts protocol data units (PDUs) from the network and stores them for later replay in the same time sequence as the PDUs were originally received. **See also:** protocol data unit (PDU). [IEEE 1278.3]

Data Validation. The documented assessment of data by subject area experts and its comparison to known or best-estimate values. (1) Data producer validation is that documented assessment within stated criteria and assumptions. (2) Data user validation is that documented assessment of data as appropriate for use in an intended modeling and simulation (M&S). [DIS]

Data Verification. The use of techniques and procedures to ensure that data meet specified constraints defined by data standards and business rules. (1) Data producer verification is the use of techniques and procedures to ensure that data meet constraints defined by data standards and business rules derived from process and data modeling. (2) Data user verification is the use of techniques and procedures to ensure that data meet user specified constraints defined by data standards and business rules derived from process and data modeling and that data are transformed and formatted properly. [DIS]

Data Verification, Validation, and Certification. The process of verifying the internal consistency and correctness of data, validating that they represent real-world entities appropriate for their intended purpose or an expected range of purposes, and certifying them as having a specified level of quality or as being appropriate for a specified use, type of use, or range of uses. The process has two perspectives: producer and user process. **See:** data validation, data verification, and data certification. [DIS]

Dead Reckoning. See: remote entity approximation.

Deaggregate. See: disaggregate. [DIS]

Distributed Interactive Simulation (DIS). A synthetic environment within which humans may interact through simulation(s) at multiple sites networked using compliant architecture, protocols, standards, and databases (DoDD 5000.59P)

E

Electronic Battlefield. See: synthetic environment. [DIS]

Entity. Any component in a system that requires explicit representation in a model. Entities possess attributes denoting specific properties. **See:** simulation entity. [DIS]

Environment. (1) The texture or detail of the domain, such as cities, farmland, sea states, etc. (2) The external objects, conditions, and processes that influence the behavior of a system (such as terrain relief, weather, day, night, terrain cultural features, etc.) [DIS]

Event. (l) An occurrence that causes a change of state in a simulation. **See also:** conditional event; time-dependent event. (2) The instant in time at which a change in some variable occurs. [DIS]

Event-Driven Simulation. See: event-oriented simulation. [DIS]

Event-Oriented Simulation. A simulation in which attention is focused on the occurrence of events and the times at which those events occur; for example, a simulation of a digital circuit that focuses on the time of state transition. **Syn:** event-driven simulation; event-sequenced simulation. [DIS]

Event-Sequenced Simulation. See: event-oriented simulation. [DIS]

Exercise. (1) One or more sessions with a common objective and accreditation. (2) The total process of designing, assembling, testing, conducting, evaluating, and reporting on an activity. **See:** simulation exercise. **Syn:** experiment, demonstration. [DIS, IEEE 1278.3]

F

Fidelity. (1) The similarity, both physical and functional, between the simulation and that which it simulates. (2) A measure of the realism of a simulation. (3) The degree to which the representation within a simulation is similar to a real-world object, feature, or condition in a measurable or perceivable manner. **See also:** model/simulation validation. [DIS, IEEE 1278.1]

Field. (1) A series of contiguous bits, treated as an instance of a particular data type, that may be part of a higher level data structure. (2) An external operating area for actual vehicles or live entities. **See:** field instrumentation. [DIS, IEEE 1278.1]

G

Graphical Model. A symbolic model whose properties are expressed in diagrams. For example, a decision tree used to express a complex procedure. **Contrast with:** mathematical model; narrative model; software model; tabular model. [DIS]

Ground Truth. The actual facts of a situation without errors introduced by sensors or human perception and judgment. [DIS]

H

Human-in-the-Loop Model. See: interactive model.

Human-Machine Simulation. A simulation carried out by both human participants and computers, typically with the human participants asked to make decisions and a computer performing processing based on those decisions. [DIS]

I

Interactive Model. A model that requires human participation. **Syn:** human-in-the-loop model. [DIS]

Interoperable. Two or more simulations are distributed interactive simulation (DIS) interoperable for a given exercise if they are DIS compliant, DIS compatible, and their performance characteristics support a fair fight to the fidelity required for the exercise. **Contrast with:** compatible, compliant. [DIS]

Interoperability. (1) The ability of a set of simulation entities to interact with an acceptable degree of fidelity. The acceptability of a model is determined by the user for the specific purpose of the exercise, test, or analysis. (2) The ability of a set of distributed interactive simulation applications to interact through the exchange of protocol data units. [DIS]

L

Live Entity. A perceptible object that can appear in the virtual battlespace but is unaware and nonresponsive (either by intent, lack of capability or circumstance) to the actions of virtual entities. **See also:** field instrumentation. **Contrast with:** live instrumented entity. [DIS]

Live Instrumented Entity. A physical entity that is in the real world and can be represented in the distributed interactive simulation (DIS) virtual battlespace which can be manned or unmanned. The live instrumented entity has internal and/or external field instrumentation (FI) devices/systems to record and relay the entity's surroundings, behavior, and/or reaction to events. If the FI provides a two-way link, the events that affect the live instrumented entity can be occurring in the virtual battlespace as well as the real world. **See also:** field instrumentation, live entity. [DIS]

Local Area Network (LAN). A class of data network which provides high data rate interconnection between network nodes in close physical proximity. [IEEE 1278.3]

M

Measure of Performance (MOP). Measure of how the system/individual performs its functions in a given environment (e.g., number of targets detected, reaction time, number of targets nominated, susceptibility of deception, task completion time). It is closely related to inherent parameters (physical and structural) but measures attributes of system behavior. **See also:** measures of effectiveness (MOE). [IEE 1278.3]

Model. (l) An approximation, representation, or idealization of selected aspects of the structure, behavior, operation, or other characteristics of a real-world process, concept, or system. Note: Models may have other models as components. (2) To serve as a model as in (1). (3) To develop or use a model as in (1). (4) A mathematical or otherwise logical representation of a system or a system's behavior over time. [DIS]

Model/Simulation Accreditation. The official certification that a model or simulation is acceptable for use for a specific purpose. **See also:** distributed simulation accreditation. **Contrast with:** model/simulation validation, model/simulation verification. [DoDD 5000.59]

Model/Simulation Validation. The process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended use(s) of the model. **See also:** distributed simulation validation, fidelity. **Contrast with:** model simulation accreditation, model simulation verification. [DoDD 5000.59]

Model/Simulation Verification. The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. **See also:** distributed simulation verification. **Contrast with:** model simulation accreditation, model simulation validation. [DoDD 5000.59]

N

Network Filter. A system to selectively accept or reject data received from the network. [DIS]

Network Node. A specific network address. **See:** node. **Contrast with:** processing node. [DIS]

Node. A general term denoting either a switching element in a network or a host computer attached to a network. **See:** processing node; network node. [IEEE 1278.1, IEEE 1278.2]

O

Operational Environment. A composite of the conditions, circumstances, and influences which affect the employment of military (or other) forces and the decisions of the unit commander or person in charge. [DIS]

P

Platform. A generic term used to describe a level of representation equating to vehicles, aircraft, missiles, ships, fixed sites, etc., in the hierarchy of representation possibilities. Other representation levels include units (made up of platforms) and components or modules (which make up platforms.) [DIS]

Protocol Data Unit (PDU). A distributed interactive simulation (DIS) data message that is passed on a network between simulation applications according to a defined protocol. [IEEE 1278.1]

R

Real Time. In modeling and simulation, simulated time advances at the same rate as actual time; for example, running the simulation for one second results in the model advancing time by one second. **Contrast with:** fast time, slow time. [DIS]

Resolution. (1) The degree to which near equal results values can be discriminated. (2) The measure of the ability to delineate picture detail. [DIS]

S

Scenario. (1) Description of an exercise (initial conditions). It is part of the session database which configures the units and platforms and places them in specific locations with specific missions. (2) An initial set of conditions and time line of significant events imposed on trainees or systems to achieve exercise objectives. **See:** field exercise. [DIS, IEEE 1278.3]

SIMNET (Simulator Networking). The prototype distributed simulation upon which distributed interactive simulation (DIS) was based. [DIS]

Simulate. To represent a system by a model that behaves or operates like the system. **See also:** emulate. [DIS]

Simulated Time. Time as represented within a simulation. **Syn:** virtual time. **See also:** fast time; real time; slow time. [DIS]

Simulation. (l) A model that behaves or operates like a given system when provided a set of controlled inputs. **Syn:** simulation model. **See also:** emulation. (2) The process of developing or using a model as in (1). (3) An implementation of a special kind of model that represents at least some key internal elements of a system and describes how those elements interact over time. [DIS]

Simulation Environment. (1) Consists of the natural physical environment surrounding the simulation entities including land, oceans, atmosphere, near-space, and cultural information. (2) All the conditions, circumstances, and influences surrounding and affecting simulation entities including those stated in (1). [DIS]

Simulation Exercise. An exercise that consists of one or more interacting simulation applications. Simulations participating in the same simulation exercise share a common identifying number called the exercise identifier. These simulations also utilize correlated representations of the synthetic environment in which they operate. **See:** live simulation. [IEEE 1278.1, IEEE 1278.2]

Simulation Fidelity. Refers to the degree of similarity between the simulated situation and the operational situation. [IEEE 1278.3]

Simulation Time. (1) A simulation's internal representation of time. Simulation time may accumulate faster, slower, or at the same pace as real time. (2) The reference time (e.g., universal coordinated time) within a simulation exercise. This time is established ahead of time by the simulation management function and is common to all participants in a particular exercise. [DIS, IEEE 1278.1]

Simulator. (1) A device, computer program, or system that performs simulation. (2) For training, a device which duplicates the essential features of a task situation and provides for direct practice. (3) For distributed interactive simulation (DIS), a physical model or simulation of a weapons system, set of weapon systems, or piece of equipment which represents some major aspects of the equipment's operation. [DIS]

Site. (1) An actual physical location at a specific geographic area, e.g., the Fort Knox Close Combat Test Bed (CCTB). (2) A node on the network used for distributed simulation such as the Defense Simulation Internet (DSI) long haul network. (3) A level of configuration authority within a distributed interactive simulation (DIS) exercise. [DIS]

V

Validation. See: data validation, distributed simulation validation, face validation, model/simulation validation. [DIS]

Verification. See: data verification, distributed simulation verification, model/simulation verification

Verification and Validation (V&V) Proponent. The agency responsible for ensuring V&V is performed on a specific model or simulation. [DIS]

Vignette. A self-contained portion of a scenario. [DIS]

Virtual Battlespace. The illusion resulting from simulating the actual battlespace. [DIS]

W

War Game. A simulation game in which participants seek to achieve a specified military objective given pre-established resources and constraints; for example, a simulation in which participants make battlefield decisions and a computer determines the results of those decisions. **See also:** management game. **Syn:** constructive simulation; higher order model (HOM). [DIS]

Wide Area Network (WAN). A communications network of devices which are separated by substantial geographical distance. **Syn:** long haul network. [IEEE 1278.3]

Appendix G – List of Acronyms

4 ID	4th Infantry Division, Fort Hood, Texas
ACE	analysis and control element
ADA	air defense artillery
ADS	advanced distributed simulation
AFATDS	Advanced Field Artillery Tactical Data System
AFB	Air Force base
AFOTEC	Air Force Operational Test and Evaluation Center, Kirtland AFB, NM
ALQ-131	a mature self-protection jammer system with reprogrammable processor developed by Georgia Technical Research Institute
AM	amplitude modulation
ANIU	air network interface unit
ARIES	Advanced Radar Imaging Emulation System
ASAS	All Source Analysis System
ATACMS	Army Tactical Missile System
ATCCS	Advanced Tactical Command and Control System
A-tracker	automatic tracker
ATWS	Advanced Technology Work Station
Bde	brigade
Bn	battalion
C4I	command, control, communications, computers and intelligence
C4ISR	command, control, communications, computers, intelligence, surveillance and reconnaissance
CAMPS	Compartmented All Source Analysis System (ASAS) Message Processing System
CBS	corps battlefield simulation
CDP	central data processor
CEP	circular error probability
CGS	common ground station
CGSC	U. S. Army Command and General Staff College
CMG	cost model guidance
Co	company
COI	critical operational issue
CONWOR	controller workstation
COT&E	contingency operations test and evaluation
CPU	central processing unit
D&SA BL	Depth and Simultaneous Attack Battle Lab
DAA	designated approval authority
DCT	digital communications terminal
DD, DT&E	deputy director, Developmental Test and Evaluation
DIS	distributed interactive simulation
DISA	Defense Information Systems Agency
DMA	Defense Mapping Agency (now National Imagery and Mapping Agency)

DMAP	data management and analysis plan
DoD	Department of Defense
DOLOS	a low-level line-of-sight driver routine
DT	developmental test
DT&E	developmental test and evaluation
EAGLE	a rule-based tactical simulation developed by the U.S. Army Training and Doctrine Command, Leavenworth, Kansas
ECCM	electronic counter-countermeasure
ESPDU	entity state protocol data unit
ETE	End-to-End Test
EW	electronic warfare
FI	functionality and integration
FM	frequency modulation
FOM	federation object model
Force (editor)	a menu option that opens the Scenario Forces Editor which is used to modify system numbers, aggregation and task force assignments for a Janus scenario
FORTRAN	a coding system for programming scientific problems to be solved by a computer
FTI	fixed target indicator
FTP	file transfer protocol
FY	fiscal year
GHQ	general headquarters
GNIU	ground network interface unit
GPC	general purpose computer
GPS	global positioning system
GRCA	ground reference coverage area
GSM	ground station module
HA	heterogeneous aggregation
HF	high frequency
HLA	high level architecture
HQ	headquarters
hrs	hours
ID	infantry division; identification
IEEE	Institute of Electrical and Electronics Engineers
IOT&E	initial operational test and evaluation
IPT	integrated product team
JAAWS	Janus analyst workstation
JADS	Joint Advanced Distributed Simulation, Albuquerque, New Mexico
JanDIS	application program - Janus distributed interactive simulation
JanPVD	Janus Plan View Display program
Janus	interactive, computer-based simulation of combat operations
JFS	joint feasibility study
JIM	Joint Exercise Support System (JESS) Intelligence Module
Joint STARS	Joint Surveillance Target Attack Radar System

JPO	joint program office
JT&E	joint test and evaluation
JTF	joint test force
Kbits	kilobits
km	kilometers
km^2	square kilometers
LAN	local area network
LGSM	light ground station module
LOS	line-of-sight
M&IS	management and integration software
M&S	modeling and simulation
MB	megabyte
Mbps	megabits per second
MI	military intelligence
mins	minutes
MITRE	company that provides engineering services
mm	millimeter
MODSAF	modular semiautomated forces
MOE	measure of effectiveness
MOP	measure of performance
MOT&E	multiservice operational test and evaluation
ms	millisecond
MTI	moving target indicator
N&E	network and engineering
NC	network coordinator
NetVisualizer™	software that displays real-time bandwidth use in a rolling bar graph format for quick visual reference
NIU	network interface unit
NTC	National Training Center
NTP	network time protocol
OIC	officer in charge
OPEVAL	operational evaluation
OPORDS	operations orders
OSD	Office of the Secretary of Defense
OT	operational test
OT&E	operational test and evaluation
PDU	protocol data unit
PM	program manager
PME	primary mission equipment
POC	point of contact
PTP	program test plan
PVD	plan view display
ROM	rough order of magnitude
RPSI	radar processor simulator and integrator
RTI	runtime infrastructure

RWS	remote workstation
SAFOR	semiautomated forces
SAIC	Science Applications International Corporation
SAR	synthetic aperture radar
SATCOM	satellite communication
SCDL	surveillance control data link
SE	synthetic environment
sec	second
SGI	Silicon Graphics, Inc.
sim	simulator
SIT	System Integration Test
SM&C	system management and control
SME	subject matter experts
SMO	system management officer
SPECTRUM®	an instrumentation suite used to measure bandwidth utilization
STAGE	Scenario Toolkit and Generation Environment; a scripted simulation by Virtual Prototypes, Inc., that is used to build complex simulations and graphically define interactive tactical scenarios
STRICOM	U.S. Army Simulation, Training, and Instrumentation Command
SUT	system under test
SWA	Southwest Asia
T&E	test and evaluation
T-1	digital carrier used to transmit a formatted digital signal at 1.544 megabits per second
TAC	target analysis cell
TAFSM	Tactical Army Fire Support Model
TCAC	Test Control and Analysis Center, Albuquerque, New Mexico
TED	terrain editor
TEMPEST	special shielding against electromagnetic radiation
TEXCOM	U.S. Army Test and Experimentation Command
TRAC	U.S. Army Training and Doctrine Command (TRADOC) Analysis Center
TRADOC	U.S. Army Training and Doctrine Command
TTL	U.S. Army Test and Experimentation Command (TEXCOM) Technology Laboratory
UAV	unmanned aerial vehicle
UHF	ultra high frequency
V&V	verification and validation
VDP	VSTARS data packet
VHF	very high frequency
VHF	very high frequency
VSTARS	Virtual Surveillance Target Attack Radar System
VV&A	verification, validation, and accreditation
WAN	wide area network
WBS	work breakdown structure
WSMR	White Sands Missile Range